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TRAC PAC:
The Next Generation

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ABSTRACT

The Transportation and Civil Engineering (TRAC) PAC is a toolkit of instructional aids originally built in 1994 to attract middle and high school students to the transportation field. Since that time, users have noted difficulties arising from the PAC's curricula, equipment, and undefined role in the classroom. This report outlines a methodology for evaluating the PAC, identifies problems with the current PAC, and develops recommendations for a substantially different next generation PAC. Key findings include the importance of curricula when compared to technology, the need to design flexible lessons that integrate well with teachers' current lesson plans, the relevance of educational standards of learning, and the availability of educational products that can leverage investments in the TRAC PAC. Technical suggestions are presented including the use of calculator-based labs, delivery of lesson plan updates via the World Wide Web, creation of modules covering a broader transportation perspective, and concrete linkage to educational standards. Results of the open-ended interviews with teachers, students, principals, and TRAC volunteers underscore the need to penetrate the classroom environment rather than relying on short answers or anecdotal information. Lessons learned from this effort are applicable to other types of program evaluation.

SUMMARY

Diverse organizations, including governments, commercial enterprises, volunteer groups, and trade associations profess a desire to improve secondary education. Accordingly, many educational outreach programs sponsored by these organizations have been initiated. These programs take different forms, ranging from one-time donations of equipment to student mentoring efforts to active partnerships with teachers. For those who seek a lasting involvement in schools, much can be learned from experiences with a transportation-oriented education toolkit, known as the TRAC PAC, which is the subject of this report.

History of the TRAC Program

The Transportation and Civil Engineering (TRAC) PAC is a toolkit of instructional aids designed by the American Association of State Highway and Transportation Officials (AASHTO) in the early 1990s to recruit high school students, "in particular minorities and women, into careers in transportation and civil engineering."(*1*) While TRAC is a broad educational outreach program, a set of equipment and curricula known as the TRAC PAC is a fundamental classroom component of TRAC. The mentality behind the TRAC program is that it appeals to teachers, students, and state transportation departments: teachers get free, interesting educational materials, students learn transportation topics interactively (not by book), and state DOTs gain a larger pool of prospective employees.

The TRAC program is administered at the state level. Once a state chooses to participate, it purchases a TRAC membership as well as multiple PACs from TRAC National Headquarters. The state is entitled to toll-free technical support as well as PAC training for a nominal fee. Typically states have given each PAC to a secondary school that either expressed an interest in the program, had strong high minority representation, or both. States are responsible for providing DOT employees who voluntarily work with TRAC schools in some fashion. States also coordinate training, usually arranging for teachers and DOT volunteers to have an annual short course with a trainer from TRAC National Headquarters, although some states provide training themselves. School and teacher selection, volunteer involvement, management support, and the program's goals vary substantially among the states.

History of One Component of the TRAC Program: the PAC

At first glance the TRAC PAC – hereafter referred to as the PAC – appears as a large black suitcase similar to the prototype that was created by 1994.(*2*) Upon opening the PAC one finds an array of materials that support 50 individual educational activities. All are intended to have some linkage to transportation: examples include an activity involving magnetic levitation, force and motion detectors used to convey physics concepts, and educational/gaming software that helps teach bridge design or graphing. Directions for these lessons are contained in two similar documents: an instructor's guide and a student's guide.

Many of the PAC materials are designed to work with one other essential piece of equipment: an IBM personal computer. State DOTs usually provide this computer with the PAC by purchasing it from TRAC National Headquarters or acquiring it from their own stock. The PAC activities that use software originally worked with Macintosh and later DOS computers, and in spite of the recent upgrade to the Windows 95 operating system, the PAC activities still largely retain their original form. The one computer concept underscores another aspect of the PAC: generally, each PAC has just one set of materials so usually only one student can do an activity at a time or the activity is used as a demonstration by the teacher.

Often the PAC is placed in a physics or technology course, although in some instances it is used in a general science class. Consequently many teachers refer to the PAC activities as "experiments". It is usually the teacher's responsibility, upon receiving a PAC from the state DOT, to sort through the materials and determine how exactly to incorporate the PAC into his or her curricula.

Current PAC Design

The PAC's present form reflects previous perceptions about TRAC's goal and how the PAC should help accomplish that goal. Understanding these perceptions is critical because they affect the very nature of the TRAC program. Hence, an observation of how the current PAC appears implies five inaccurate assumptions:

- The hook for *teachers* is that they get free equipment in the form of a PAC and computer. They will take extensive advantage of this free PAC to accomplish transportation-related activities.

- The hook for *students* is that the PAC is high-tech. They will be fascinated to the extent that they are satisfied to watch one student or the teacher conduct the PAC experiments.

- The PAC should be defined as a *tangible set of materials* from which teachers and volunteers can develop transportation-related lessons. Designing curricula is easy; materials are most important.

- The *transportation field* consists of professionals who often use motion sensors, DOS-based graphing software, and physics experiments in a stepwise linear fashion.

- The hook for a *transportation department* is that participation in the TRAC program will encourage interest in transportation careers, an interest that does not need to be quantified.

These assumptions may not reflect the original intent of the PAC designers; for example, it was initially stated that two-person TRAC teams consisting of civil engineers and college students – not educators – would usually teach the PAC modules. Whether the change in practice from TRAC teams teaching the modules to educators was deliberate or a result of migrating a pilot program to a national effort is not clear. It is evident that those five assumptions reflect the PAC as it is now delivered. The problem is that they are wrong.

Root PAC Problems

Anecdotal comments have been reported from state DOTs and teachers that one component of the TRAC Program – the PAC – is not working as intended. Agencies have observed that teachers are not using the PAC. Volunteers have had to be creative when visiting the schools, for it is often not the case that the PAC experiments perform as intended. Equipment failures, outdated technology, and poor curricula are recognized by TRAC National Headquarters and AASHTO as symptoms of underlying problems with the current generation PACs. Although both organizations are taking incremental steps to improve the existing PAC, such as rewriting curricula and updating the operating system, there is a widespread sentiment that a substantial overhaul of the PAC is required. In short, AASHTO would like to revamp the PAC and reconsider its fundamental nature.

Study Purpose and Audience

As a precursor to a larger effort where a prototype next generation PAC will be designed, this study explores the utility of current PACs, develops recommendations for the next generation PACs, and provides practical examples for achieving those recommendations. The report has three distinct audiences: *administrators* who want to know what TRAC can accomplish and how its impact should be evaluated, *transportation personnel* who value school involvement but would like guidance for translating career experiences into a classroom-ready format, and *TRAC personnel* who will be designing or working with future PACs. We acknowledge the large amount of existing literature that describes how a program should work, however, we believe this document presents unique, valuable lessons for how to improve an educational outreach program - lessons that in this case can only be learned through extensive interaction with practitioners.

Methodology and Results

More than 50 on-site, in-depth interviews were conducted with teachers, principals, students, and TRAC Volunteers from 16 schools in the states of Colorado, Maryland, New Mexico, Virginia, and West Virginia in order to evaluate the current PAC, identify the salient features of what constitutes a desirable educational activity, and obtain recommendations for the next generation PAC. The interview schedule, shown in Appendix A, allowed the investigators to target the interviewees' areas of expertise. State and national education standards are critical to relating new PAC modules to the classroom, as documented in Appendix B. Theories of learning, descriptions of other commercially available educational products, and sources of low-cost activities comprise the literature review that illuminates how to create viable modules.

The methodology employed illustrates the value of open-ended discussions with PAC end-users as opposed to multiple-choice survey responses. Appendix D, which details these interview results, indicates that teachers, volunteers, students, and principals have excellent ideas for improving the PAC and moving it into the classroom. Interviewees articulated fundamental problems such as equipment failures, a narrow focus on topics more akin to an advanced physics course than the transportation field, the inability to directly involve an entire class of students, the lack of educator involvement in the development of PAC curricula, and the difficulty that teachers and students face in trying to prepare and conduct experiments in a timely manner. Interviewees also pointed out the strengths of the few interactive PAC activities, such as problem solving and visualization of theory. Although the current PAC goes largely unused, the ideals underlying its creation, such as relating math and science to real-world applications, are laudable. Educators' usually highly positive view of the volunteer indicates his or her essential role within the TRAC program, which is looked upon much more favorably than the PAC itself. Appendix D also shows the wide variation in opinions: clearly some teachers do find value in a few existing PAC modules (those few should be retained but substantially changed as indicated in this report).

Vision for the Next Generation PAC

A PAC substantially different from current practice is recommended. The report outlines a vision for an educational toolkit that does not resemble the current one with one significant exception: the role of the volunteer. In the future, as is the present case, the volunteer is a fundamental component of the TRAC program. Otherwise, however, the PAC will be substantially different, especially considering the five assumptions previously cited:

- The next generation PAC's foothold in the school system is that it is a *resource expressly designed for teachers to meet education standards*. Although a module might involve bridge building, for example, it would be presented as an activity that teaches the appropriate standard of learning pertaining to the specific class. This shifts the PAC from its current status as being an "extra" piece of equipment to a "solution" for meeting required education standards.

- The *new PAC activities will attract students* because these activities are interactive and geared toward diverse interests, ages, and abilities. Lessons that enable one to create, rather than watch, can hook students if designed in an educationally sound manner.

- The phrase "PAC" is almost an anomaly as it will become *an evolving set of activities* from which teachers can choose some rather than being forced to purchase an entire suitcase. The delivery mechanism proposed herein provides a forum for teachers, volunteers, and students to continuously improve the PAC, discarding useless activities and creating new ones, focusing especially on the curricula. Clearly curricula matter more that the raw materials.

- The new PAC has a *much broader transportation focus*, attracting not only civil engineers but diverse *subject* areas of policy, administration, economics, environmental sciences, ITS, and public relations and diverse *positions* at the engineering, technician, support, and management levels. The future PAC reflects a shift in TRAC's mission toward emphasizing transportation's interdisciplinary nature and active involvement in the schools rather than simply being an equipment donor.

- Transportation departments will rightfully want to *quantify the benefit of the TRAC program,* including the PAC component. A realistic and cost-effective means of obtaining feedback from educators and volunteers is to track student performance and give small incentives for reporting these data, in the manner outlined in this report.

Building the Next Generation PAC

Recommendations for achieving this new vision begin with simple improvements that can be done immediately, continue with the development of new modules, and conclude with the creation of a dynamic, rather than static, PAC. Low-cost hands-on activities are critical such that future PAC modules can be done by students rather than watched as a classroom demonstration; while high-tech materials or advanced graphics can be nice, being hands-on is far more important. Lesson plans are more significant than raw materials: a good activity might simply involve paper, pencil, and a ruler if creativity or scientific curiosity is encouraged. Desired curricula traits include open-ended questions, problem-solving components, an interdisciplinary focus, and skills that will be employed outside of school. Students recognize the occasions when they perform an academic-only experiment, and volunteers want examples that reflect real-world transportation careers. Unlike the current PAC, educators and volunteers should be involved with creating the curricula for these activities.

The future PAC modules should be designed for multiple grade levels and subject areas. Just as transportation is a broad field, it is appropriate to use the PAC in classes other than physics and technology, such as general science, social studies, and other courses where interdisciplinary topics are desired. New PAC modules are described in the areas of construction, operations, planning, and relevant technology skills such as CADD and programming. The way in which these activities are presented is important; for examples, as detailed in the Recommendations chapter, a module entitled "Investigate a Car Crash!" may appeal to students if it can allow them to organize data from disparate sources, learn about advanced technology, and defend their conclusions in a structured format. Although the recommendations detail specific changes concerning graphics, equipment, computing platforms, software, and technologies such as calculator-based labs, a fundamental change in the future PAC is that it represents a process as much as a physical assortment of activities. The epilogue illustrates this process by using one volunteer's suggestion – a roadway location scenario - to envision a new type of PAC activity that is hands-on for an entire class, meets state standards of learning, and reflects actual transportation jobs.

The TRAC program, including the volunteer's visits to the classroom and potential organizational connections between state education and transportation departments, determines TRAC's standing in the classroom as much as the PAC. Even though schools are given or sold educational supplies from numerous other sources, TRAC's niche in the classroom can be the long-term involvement of the TRAC volunteer and associated support network. Because the next generation PAC places such an emphasis on communication at the institutional and individual levels, personal contact remains essential but can be supplemented by using the World Wide Web to handle logistical problems of keeping information or software updated.

Report Overview

Readers who are most interested in the *specifications for the next generation PAC* are referred to the recommendations chapter (pp. 34-46). The epilogue illustrates a process for marketing TRAC, creating a new module, and phasing in new modules; this should interest *transportation administrators* who are considering new visions of the program. Future *PAC designers* will be interested in the findings and discussion (pp. 14-30) which summarize the interviews and review the literature. In particular, theories of how students acquire information and the sources of low-cost educational activities offer insights into types of activities that are more likely to be successful in the classroom. *Education administrators* who work with a career-related program may wish to review how the PAC links to state and national standards of learning, as described on pp. 30-32 and in Appendix B.

Finally, *program evaluators* are referred to the research approach chapter (pp. 7-13) as it describes how one may acquire information about a program in the absence of survey data. The multiple interviews were time consuming and a logistical nightmare, but yielded a rich understanding of why the PAC needs to radically change if it is to sustain a classroom presence. Frustrations, successes, and energy levels exhibited by those associated with the program offer a context for realistically assessing the PAC and are a source of practical ideas. The results of applying this methodology, as compared to previous efforts to evaluate the TRAC program, prove that one cannot substitute simple tallies for in-depth interviews.

Accordingly, development of the next generation PAC – or any educational aid - should be a continuing process that fully uses the expertise of teachers, students, principals, and volunteers who are the PAC's customers.

INTRODUCTION

BACKGROUND

Instructional aids in the classroom have the *potential* to greatly enhance the learning experience for several reasons. *First*, each individual uses different mechanisms for acquiring and synthesizing information. Some students acquire information most easily through absorption of written material, some are auditory learners, and still others benefit from the active (or participatory) method of learning. A *second* reason is that even if all students were to learn in exactly the same manner, these aids help the students acquire knowledge that cannot be learned through other means in the classroom. A common example is the development of laboratory skills, including application of the scientific method to a specific research area. Although the student may learn the scientific principles of a particular subject via the passive method, it is the act of experimentation that can help the student understand how to formulate a research question, why it is necessary to document procedures such that they can be replicated, and when it is possible to draw conclusions from observations. *Third*, instructional aids entertain. This is not always lauded as an educational goal, but in practical situations these aids may be a welcome diversion from more tedious tasks, especially when one is required to keep pupils in the classroom for a fixed amount of time. *Fourth*, instructional aids can teach a specific objective that school systems are emphasizing, such as the relationship of an academic subject to a career, the value of working together, or problem solving skills. *Finally*, instructional aids can stimulate a student's interest beyond the material that has been presented. Even though a student may learn the material at hand, many teachers view the educational process as a way of enabling each person to pursue a field in greater detail outside the classroom. In this sense, an instructional aid is an activity that supplements or replaces an intended lesson plan.

The Transportation and Civil Engineering (TRAC) PAC is a toolbox of instructional aids designed by AASHTO to be used by teachers and volunteers to introduce middle and high school students to the transportation field. The current PAC contains modules in eight different areas such as the physics of motion, sound, magnetic levitation, and Intelligent Transportation Systems (ITS). Hardware such as motion detectors, force probes and sound sensors, software packages (e.g. SimCity, a game that allows students to build and manage a city over time), and curricula guides for students and teachers are included within the PAC. Many of the PAC modules require an IBM-compatible Personal Computer (PC), and the entire PAC without the computer is available from TRAC National Headquarters for a cost of approximately $1,200. Typically the PACs are purchased by state Departments of Transportation (DOTs) which then make them available to schools in conjunction with a state DOT employee, known as a TRAC volunteer, who may visit the classroom to explain how the PAC modules relate to transportation careers. Of course there are variants to this process: schools may purchase the PACs directly and volunteers may be very or sporadically involved with the PAC, depending on the school, the volunteer, and the state.

The National Cooperative Highway Research Program (NCHRP) has determined that the PAC needs substantial revision for several reasons. Technology has been one problem; for example, one of the PAC's math modeling applications known as "PC-Solve" does not use present day operating systems. NCHRP 20-7(78) offers some additional views about the suitability of the current PAC: findings 14 and 15 state respectively that "The cost of TRAC materials and equipment is a concern of many of the Regional Centers" and "There was considerable dissatisfaction with the availability of TRAC equipment and the overall quality of the experiments supplied with the TRAC PAC's [sic]".(3) The same document alludes to the importance of the PAC's lesson plans in its recommendation to "focus on curriculum and activity development, rather than equipment and computers." Finally, comments made at the 3rd Annual TRAC Conference in 1998 suggested problems with equipment malfunctioning, a lack of active teacher participation, and the need for activities to be written from a multidisciplinary perspective.

To continue and expand TRAC's classroom involvement, the American Association of State Highway and Transportation Officials (AASHTO) desires to improve the PAC. This motivation is the genesis of this study.

PURPOSE AND SCOPE OF WORK

The purpose of this research may be succinctly stated as "to evaluate the current PAC and to make detailed recommendations for the next generation PAC." These recommendations reflect an understanding of the strengths and weaknesses of the current PAC modules in light of teachers' classroom needs. To make the recommendations feasible, they consider state and national standards of learning, types of curricula being emphasized by schools, the school environment, and the factors that help TRAC volunteers and teachers use a module effectively. Ultimately these findings will be used to guide a larger project that will produce a prototype next generation PAC. Hence these recommendations seek to give some guidance as to what future PAC designers should try to accomplish. The product of this report is thus not a prototype but instead is a vision for what the next generation PAC should do.

To decipher why the PAC's customers are satisfied or dissatisfied with the PAC, open-ended interviews have been conducted at schools or TRAC Regional Centers in several states. The scope of this effort, therefore, has focused on understanding what makes an educational aid be used and why the PAC succeeds or fails rather than gathering statistical information concerning PAC module use.

It is acknowledged that one could argue this interview approach suffers from the lack of a comprehensive survey of many schools, and that therefore a better method would be to prepare a detailed questionnaire that asked respondents either to select answers from multiple choice questions or to provide answers to free-response questions about educational ideals. The key to this project, however, is to develop *insights* into the next generation of the PAC. The way to accomplish this is to delve into the details of how teachers, students, principals, and volunteers use instructional aids such as the PAC and what makes these aids successful or useless. NCHRP 20-7(78) has already identified responses to general overview questions (e.g. 42% of the respondents "mildly agree" that the PACs are reasonably priced.)(*4*) More in-depth information is needed than what can be acquired via a survey.

RESEARCH APPROACH

Five distinct target groups were interviewed from select TRAC states: teachers, students, principals, facilitators (also known as TRAC volunteers) who are usually but not always Department of Transportation employees, and former students. Although all five groups are important, the primary emphasis has been on teachers, as they are the gatekeeper of the PAC and ultimately determine whether or not it is used. The interview questions were designed with the assistance of two educators (one at the high school level and one at the college level) who also reviewed the results at several critical points during this research, offering feedback, ideas, and references.

The interview process was designed to accomplish two basic goals. *First*, there is a need to ascertain advantages and disadvantages of the current PAC: which modules are most useful, what technologies tend to captivate the student, and which lesson plans require too much preparation time to be feasible. From this first goal, it was possible to identify what characteristics make a particular module worth using in the classroom setting. Yet there is a *second* goal– to learn what teachers would envision as an "ideal" PAC. The PAC is one of many instructional aids available for teachers, and other aids have been tried in schools, with greater or lesser success. If teachers, students, principals, or volunteers have experiences from these other types of instructional aids that would be relevant to the next generation PAC, then these experiences need to be examined during the interview process. Hence because of the second goal, some of the questions are more forward looking in terms of the future PAC.

To supplement the interviews, literature was reviewed pertaining to state and national standards, educational products available from commercial suppliers, and theories of learning. For clarity, this review is discussed in the appropriate sections within the next chapter entitled "findings and discussion." In particular, consideration of the theories of learning served to clarify key principles that teachers find necessary in any instructional aid that is to be used in the classroom.

INTERVIEW FORMAT PREPARATION

The first step in preparing to meet with respondents was to review the literature on interview technique and questionnaire development. The literature outlines several useful methods for developing questionnaires and the interview process. It has been stated that of the three types of questions one may ask in an interview – questions that require selecting an answer from a list of responses, questions that provide numerical data, and open-ended questions – it is the open-ended questions that are most challenging and which tend to become more difficult as the interviewer needs to probe for additional information from the subject.(*5*) As this type of question was asked frequently within the scope of the PAC interviews, it becomes critical to minimize errors associated with this strategy. Two common errors suggested in the literature are (1) leading the respondent to give an answer in the interviewer's own words rather than the respondents, and (2) failing to obtain additional information from the subject when the answer is ambiguous. The greatest danger of these errors is that they may serve to bias results toward the expectations of the interviewers. Since in this case the interviewers did have some a priori expectations based on attendance at the AASHTO TRAC Annual Conference as well as information gleaned from previous TRAC literature, an emphasis was placed on ensuring that questions were asked and answers recorded in an unbiased manner.

It must be stated, however, that this goal of wanting to avoid probing error can cause a potential conflict with the desire to acquire interview subjects in the first place. Teachers, volunteers, and students have a very limited amount of time, and in order to quickly gain credibility with these audiences, the investigators realized it was necessary to become knowledgeable of the subject material and to demonstrate to these audiences that their insights would be put to good use. Hence while the various subject areas shown within the interview questions may have been prompted by the investigators' prior expectations, the questions themselves allowed the interviewees to give information that might support or reject these expectations. For example, the question "How do PAC modules or instructional aids fit within your program of studies or standards of learning?" was included because it appeared that certain PAC modules suffered from not having a clear place within the scope of what students are required to learn. Yet it was up to the teachers to give an answer that suggested or denied that this was a hindrance to PAC usage.

Another concern likely to arise within the interview process is how to handle answers of uncertainty. Users of the PAC have disparate backgrounds: some teachers, for example, may employ the PAC on a regular basis and enjoy support from TRAC volunteers, whereas others may use the modules sporadically. Given the breadth of the PAC, it is unlikely that a single user – teacher, student, administrator, or volunteer – would have complete familiarity with all aspects. This suggests the possibility that interviewees might indicate expressions of uncertainty in conjunction with their response to a question (e.g. "I'm not really sure, but it appears that module *x* requires too much preparation time"). It has been suggested that in addition to the final answer given by the respondent, one should also include some measure of the uncertainty if this was part of the response; findings by Mathiowetz imply that the information associated with uncertainty can be as important as the remainder of the response.(*6*) Where it could not be resolved, uncertainty is reflected in the syntheses in the form of a respondent not answering a question or not having adequate information. Usually, however, uncertainty indicated that the question was not clear; this was handled with additional neutral probes to clarify the question.

In sum, it is important that the interviewers use techniques that do not bias the respondents but rather elicit additional information. The University of Michigan's Institute for Social Research offers several techniques that may help to objectively obtain clarifying data without steering the interviewee toward a response envisioned by the interviewer.(*7*) These techniques were practiced by the investigators over the course of the discussions with school personnel, students, and TRAC volunteers. Techniques include:

- *repeating the question*. A single verbatim repetition of the question is effective in cases where the respondent simply needs more time, or to hear the question again. In practice, the interviewers found this to be even more useful than originally thought.

- *repeating the response*. This allows the respondent to "double-check" the information they are providing.

- *keeping quiet*. It is tempting to speak immediately after the question owing to the limited amount of time teachers may have. Yet in some instances simply asking a question and then allowing the silence to occur can help respondents formulate their own ideas.

- *using key phrases that do not bias the respondent.* Questions such as "What do you mean?", "Could you give me some more information about that perspective?" or "Why is that?" may catalyze additional opinions without biasing the respondent. In particular, the questions "Could you elaborate on that" and "Tell me more about that" proved useful.

Of significant importance is that the investigators know the objectives of the questions: to identify the salient characteristics of the PAC that are successful or useless and to employ this information to envision the next generation PAC. Familiarity with these objectives enables the interviewers to probe for additional information with minimal bias. The interview schedules for teachers, students, volunteers, and principals is shown in Appendix A.

MAKING CONTACTS

Schools within five states were selected for interviews. Virginia was selected because of its proximity to the investigators. Maryland and West Virginia were also selected in part because of their proximity and in part because they are reputed to have active TRAC programs. Colorado and New Mexico were selected because of their active participation in TRAC and their diverse environments, especially considering the other states are in the eastern section of the U.S. Finally, a representative from South Africa was contacted because of that country's participation in TRAC and interest in PAC improvement.

A significant amount of time was spent contacting prospective teachers, students, principals, and TRAC volunteers within the various schools and state Departments of Transportation. This was more challenging than expected; in some cases teachers are not permitted to make long distance calls. Hence a variety of methods – fax, telephone contact, paper mail, and electronic mail – were used to make the initial contact. It was necessary to be both persistent and flexible: for example, initially many teachers would indicate there was no point in talking to the principal, since he or she would not be familiar with the TRAC program. It was usually only after noting that the principal could shed light on institutional obstacles to acquiring an educational aid that an interview was granted.

For the states of Virginia, West Virginia, and Maryland, the investigators handled the interview logistics themselves. Typically this would entail contacting the TRAC director for that state and obtaining from that director a list of recommended schools that would be suitable to interview. Schools were initially chosen for their high level of PAC usage, their ability to provide feedback on the PAC, or their representation of diverse environments. Then, a telephone contact would be made with the teacher, where an investigator would briefly explain the purpose of the upcoming interview and arrange a possible interview time. Next, an investigator would fax a one-page cover letter to the teacher, which was then followed by a paper mail of the same letter, a summary of the proposal, and a tentative interview schedule. If applicable, the investigator would repeat this process for the principal of the school and the TRAC volunteer; in some cases the teacher preferred to be the contact point for scheduling an interview with the principal and in other cases the teacher preferred that the investigators handle the logistics. Often several phone calls would be made over a period of a few days so that the investigator could ascertain a time and date that were mutually acceptable to all those who were being interviewed. In Maryland, the TRAC director had contacted school representatives and TRAC volunteers and let them know that the investigators would be calling them shortly. This action helped immensely and the investigators were extremely grateful.

For the states of Colorado and New Mexico, the investigators provided introductory materials to the TRAC Director who handled all the logistics directly. This assistance was crucial as it allowed the investigators to accomplish the interviews in a single trip to each state. Additionally, the directors gave some insight into the schools that were being visited which helped prepare for the interview. In New Mexico, the director selected schools such that they represented the full range of socioeconomic and demographic characteristics of the students and environments.

SUMMARY OF WHO WAS INTERVIEWED

The end result of the visits to the five states was that the 16 schools were a diverse sample in terms of type of location (urban, rural, suburban, and one Native American reservation), percentage of minority enrollment, grade level (intermediate and high), funding source, and type of school (magnet, center for at-risk youth, and general). Over 50 separate interviews, many with multiple interviewees, were conducted, as detailed in Table D-1 of Appendix D and summarized in Table 1 below. Note that most of the TRAC personnel were DOT volunteers but some were volunteer leaders, directors, or affiliates with other institutions.

Table 1: Summary of Schools and Personnel Who Were Visited (or contacted by telephone)

	Teachers	Students	TRAC Volunteers/Other Personnel	Principals
Colorado	3 schools	1 school	7 DOT volunteers	2 schools
Maryland	3 schools	3 schools	4 DOT volunteers, 1 FHWA volunteer	1 school (by phone)
New Mexico	4 schools	4 schools	7 DOT volunteers, 1 Research Bureau Chief	3 schools
Virginia	4 schools	2 schools	1 DOT volunteer	2 schools (1 by phone)
West Virginia	2 schools	2 schools	2 DOT volunteers (1 by phone) 1 WVU volunteer, 1 DOE representative	1 school
South Africa			1 manager (by phone)	
TOTAL:	16 schools	12 schools	26 personnel	9 schools

In some cases it was simply not possible for the interview to be conducted as planned; for example, in one instance, the principal had planned to be present but suddenly had to attend another meeting when the investigators arrived at the school. In other instances, teachers indicated that they would prefer to first schedule the interview with the teacher and then at a later date have the investigators interview the students, which would have necessitated return trips to the school. This occurred in part because the project began September 1 which coincided with the start of the school year and in part because many schools were acquiring new PACs.

Table D-1 of Appendix D, however, shows that interviews were conducted on the same day when possible. Each day would vary, but often the interviewers spent between four and six hours at a school, depending on the schedule of the teacher, students, principal, and volunteers. Overall, most teachers were very willing to be interviewed once they could fit this time into their schedule. Some teachers could permit only an hour; others could permit a longer amount of time. Some teachers preferred to use their planning period, others preferred after school, some preferred to stay in the school for discussion whereas others chose to go out to lunch with the interviewers. In short, it was important to be flexible, as a teacher's time is a valuable commodity!

THE PROCESS OF CONDUCTING THE INTERVIEWS

Examples of specific questions that were asked are detailed in the interview schedules of Appendix A. Yet *how* the questions are asked mattered as much as the questions themselves.

It had been suggested that the interviewers should avoid using negative value laden terms, such as "What is bad about module *x*" as this could cause respondents to give a more negative response than intended. Instead, in that case, one should consider "What is challenging about module *x*?" The interviewers did, in fact, find some initial traces of interviewee reluctance to criticize the modules; for example, one principal wondered aloud if he was supposed to give some type of "politically correct" response. Given the duration of the interviews, however – ranging from 20 minutes with a principal to an hour or a few hours with the teachers – it was possible to clear the hurdle of asking for negative responses by being frank with the respondents as to the meetings' purpose. With some probing, the results of the discussion show that indeed it was possible to get both positive and negative opinions.

Benefits of Having Two Interviewers

The value of having two interviewers was originally thought to be greater accuracy in recording. For many of the interviews, there were two persons who listened to what was said, although in some cases one person heard a tape. Each interviewer seemed to catch details or clarify a point that the other would have missed.

Yet hindsight suggests a more important value of having two interviewers than was recognized initially: two persons can ensure that all questions are asked in a coherent manner and may, in fact, put respondents more at ease, especially since one interviewer was male and one was female. The reason for this opinion is that there were several situations where one interviewer would ask a question and the respondent would give a response that did not answer the question. Then, the second interviewer would ask the same basic question but with different wording or the same wording, and this time the respondent would answer the question. One speculates that the reason may have been that some respondents simply needed to hear the question more than once or needed time to think about it.

Obtaining Responses from Students

Teachers and principals are professionals capable of articulating their thoughts clearly. Students were also willing to be interviewed, but the challenges were greater, especially because of variations in format. For example, in one 8^{th} grade class, the investigators were given the entire class period – 48 minutes – with two different classes of students. The method that engaged these students was to behave as a teacher by asking the students questions and obtaining answers from them. This started with "Does anyone know who I am" and moved into a discussion regarding what is done by the state DOT. Techniques included asking students their names, asking them to comment on each other's responses, circulating around the classroom, and shifting topics if interest waned. After between 20 and 30 minutes, the interviewer gradually moved the discussion to focus on specific lessons that had been interesting or boring for the students, and then the discussion focused on the PAC as appropriate. In the last minutes of the period, students were asked to answer the following question: "If you were building a new PAC, what is one thing you would change, add, or remove?"

In other classes, especially because of the increase in age at the high school level, different formats were employed to elicit information. When students had not used the PAC or could not recall it, one tactic was to ask them to think of an experiment or activity they had done in school and then to write about it, whether the activity was excellent or terrible. At the same time, some students preferred to take a corrective course of action, designing their own experiment. In one school in Maryland, for example, students were guided through this assignment in a series of five steps: first describe the experiment or activity, second describe what would be learned, third, mention what made this activity successful or a failure, fourth describe any “tricks” or “ideas” necessary to make the experiment a success, and finally state anything that would should be done differently if the experiment is to be repeated.

A variation on this tactic, again when students knew only of a few or no PAC activities, was to describe and list the PAC activities in one column on the board. Before doing this, though, the interviewer would spend between 15 and 25 minutes asking the students to list topics that “are included within the scope of transportation.” Hence the students might list a wide range of items, such as engine design, race car driving, designing better roads, managing traffic, and deciding where to put a road (one student pointed out that her house would be demolished by an expressway). Then, students were asked to relate the two columns showing the PAC activities and the transportation issues. In some cases students would see some relationships, however, usually they would indicate there was not much of a connection between the two columns. Then the interviewers would ask the students to design activities that would relate more strongly to the real-world transportation topics than the original PAC modules.

Working with Students

After a few visits to various schools, the interviewers began to notice a recurring theme: rarely did what was written by the students capture all that they said aloud; in fact, the short summaries that were written by the students sometimes just scratched the surface of what they knew. Thus in a couple of classroom visits the interviewers had the students, in groups that they formed themselves, develop their “ideal” transportation learning activity by writing on flip charts and then presenting the results to the class. In some cases the oral presentations had a lot of enthusiasm behind them; while the students used humor quite a bit, they were outgoing and seemed to enjoy answering questions. Some students drew figures, even though this was not requested. These figures are included with the interviewee responses in Appendix D.

The amount of coaching given to the students during this process varied from none to a lot. Some students were fiercely independent, did a very good job of developing their own ideas, and did not seem to want any help from the interviewers. There were some students at the other extreme, who did not know where to start: in those cases, then, an interviewer would talk with the students to elicit ideas that interested them, such as road rage, crashes, traffic congestion, and highway construction. Generally, circulating around the room while the students did this group work seemed necessary in order to keep things on track and to answer questions: for example, one group of students had heard of the term “GIS” but wanted to know what it meant; at other times students wanted clarification on what the assignment was. With discipline one could accomplish this within a 50-minute period, but generally the interviewers preferred the 90-minute class, with the ability to use all of the time if required.

In sum, there was a lot of flexibility in terms of how one could get feedback from the students. The selection of the *method for acquiring student input* (asking the class questions as a whole, working with the students in smaller groups, having the groups develop lesson plans, or having individual students write up activities), the *amount of introductory information* that was given (ranging from very little up to a 30 minute discussion on transportation and the role of the PAC), and the *specific work that students were asked to do* (evaluate the PAC modules, describe their own “new” transportation module, or describe school activities that they liked/hated) varied by class. While the age of the students and the amount of exposure they had had to the PAC were factors in deciding how to handle the student interview, perhaps the biggest factor was the interviewers’ “reading” of the students to determine what would work best in that particular group. This required one to change formats if discussion did not flow; in one class, having 12 students in a circle identify what they liked or disliked was not productive, perhaps owing to those students being ill at ease with speaking in front of their peers. Hence after approximately 20 minutes the interviewers pointed out that this had been an “introductory” session and that now the students could flesh out activities in smaller groups with members of their own choosing; the change seemed to help matters. Prior teaching experience on behalf of one interviewer proved extremely helpful for handling these unanticipated situations.

After reviewing student responses, the reader may be curious as to how well the interview went. The rapport varied by class and hinged on two factors. *First,* did the interviewers give the students enough introductory information? In at least one classroom, for example, a student wanted to know why transportation was even an issue; up until that point in the discussion, the interviewers had failed to mention that some state DOTs are facing a shortage of qualified personnel as well as the fact that transportation accounts for a tangible portion of the gross domestic product. The *second* critical factor was "could the interviewers establish a frame of reference for the assignment at hand?" One case where this was not done well was in a small high school where the open-ended questions simply did not work well. In retrospect, at that particular school, a better tack might have been to simply question the students in regard to the sound experiment that had been conducted by a TRAC volunteer earlier in the class. Fortunately, in that particular case, the teacher and the volunteer were present both for the student and teacher interviews and, after the students had left, these two individuals were able to explain a bit more the meaning underlying abbreviated student comments. The interviewers also conducted a telephone interview a few days later with one student, who had been absent that day, which yielded supplemental information.

Interpreting the Responses

In synthesizing the teacher, student, principal, and volunteer responses shown in Appendix D, the investigators sought to achieve three distinct goals. The first was to organize the responses under the appropriate categories. For example, some respondents, when commenting on specific PAC modules, would at the same time list non-PAC activities that had been successful. It was more convenient to list these two types of information under two separate categories. The second goal was to use language familiar to the respondent; for example, a teacher might use the term "car acceleration" rather than the term "motion fundamentals." The third goal was to make sure that the interviewer's interpretation of what the interviewees said matched. This third goal was the most difficult and at the same time the most important, because it required looking beyond the actual words uttered by the respondent in order to comprehend their meaning. For example, one physics teacher had many excellent ideas for what would work in the classroom. When asked for general characteristics of why these activities were successful, he would not respond in generalities; he would simply name an activity. Yet in listening to his examples over the course of the meeting, one would catch key phrases that did, in fact, answer the general question, such as "less is more" and "do not present science as a set of expectations." In this case, the interviewers noted these ideas in italics along with his specific examples under the category of "What works [besides the PAC]?" The respondent was then free to see how these thoughts had been interpreted by the interviewer, and if there were any changes necessary he could make them.

Verifying the Responses

Interviewees were provided a synthesis afterward and given the opportunity to make additions, deletions, or modifications. The investigators chose to fully document the interviewees' opinions, rather than abridging them, in order to ensure that those opinions were understood. The investigators placed an emphasis on verifying that the narrative as written reflected the full views of the interviewees.

Consequently effort was expended in order to ensure that the interviewee received the narrative and had a chance to verify its accuracy or make modifications. As with making the initial contacts, this required a willingness to use email, fax, regular mail, and telephone (including collect calls) in order to obtain an affirmative response from interviewees. For the states of Maryland, Virginia, and West Virginia, each interviewee was contacted directly by an investigator following the meeting; the only exception was one volunteer who had since changed jobs. (In that particular case, however, the volunteer had been interviewed with three other volunteers who were able to confirm the accuracy of the corrected narrative). For the states of Colorado and New Mexico, multiple copies of the narrative were given to the state TRAC directors, who agreed to take responsibility for distributing the narratives to the appropriate persons. Aside from a few misplaced names, the Colorado director indicated that no interviewees had found errors in the synthesis. The New Mexico director and his staff did relay a few corrections provided by the interviewees, which in turn led to follow up discussions for further clarification.

In short, interviewees often indicated that the narrative was acceptable as is or only needed minor corrections. There were a couple of cases, however, where interviewees had multiple or significant corrections, and in those instances especially we were glad to have initiated the verification process. The only exception to this process is the *oral* comments recorded from current students. While teachers were given transcripts of what they and their students had conveyed, teachers were not required to verify the student interviews. Because the students often provided *written* comments, however, this problem was kept to a minimum.

The end result is that Appendix D reflects interview narratives with teachers, principals, volunteers, and students that have been checked for accuracy and hence should be a reliable direct source of information.

FORMULATING THEMES

The interview responses shown in Appendix D reflect a great deal of qualitative data. In order to analyze these data in a coherent manner, intrinsic themes that capture the "gist" of the responses were identified. Not all themes are applicable to all responses, but disparity may be explained within the background of the specific interviewee or the context of the response. For example, several teachers noted a problem with a particular piece of equipment whereas one very experienced teacher indicated that the piece of equipment gave him no trouble.

The emphasis in scanning the interview responses has been on developing insights, hence there are situations where a single respondent articulated in detail far better a phenomenon than can be accomplished by a collection of superficial responses. For example, while many teachers noted that "problem solving" is important, one principal went so far as to outline the characteristics of a problem solving activity, yielding a set of criteria that may be used in module development. Hence the collection of themes is a means of gleaning some of the essential concepts from the interviews rather than a repeat of the text shown in Appendix D.

The themes also gave a context with which to evaluate other sources of information, such as state standards of learning, commercial products from educational suppliers, and theories regarding how students acquire information. In many instances interviewees would mention a key element without describing it in detail, such as the types of equipment available in schools. The literature review then served to more fully describe this equipment, including prices, availability, and supporting lesson plans. These themes – both from respondents and from other sources – serve as a way of structuring material in the "findings and discussion" chapter that follows.

FINDINGS AND DISCUSSION

The results of this research are discussed in this chapter in four broad sections: responses from interviewees; the literature review that included theory, practice, and the experiences of other educational outreach organizations; the impact of standards of learning (SOLs), and observations exemplifying the challenge to monitoring a state's TRAC program.

Interviewees used the words "PAC" and "TRAC" interchangeably. For clarity in this discussion, the term "PAC" refers to the physical toolkit of educational materials that are used in schools; hence "PAC" designates equipment, manuals, and curricula. "TRAC", on the other hand, designates the program, such as the training of teachers, the involvement of the volunteer, and the flow of communication between TRAC National Headquarters and the state TRAC centers.

INTERVIEWS WITH TEACHERS, STUDENTS, VOLUNTEERS, AND PRINCIPALS

Ascertaining which PAC modules tend to be used gives a baseline for understanding the PAC's role in the classroom. Yet it is the sections that follow – the classroom environment, what teachers want in an activity such as the PAC, how specific modules are used, and finally, the pluses and minuses of the current PAC and the TRAC program as a whole – that clarify what future PAC designers should know.

Which PAC Modules are Used?

Appendix D shows that not all modules are used by all schools, in fact, usually each school only uses a few of the modules and some schools use hardly any at all. Table 2 summarizes the interview results by module; with an X designating a module that was used, a "T" designating that a module was tried but not used (or used unsuccessfully), and an "F" indicating that a module will be used in the future. When two teachers from the same school gave conflicting options, then both answers are shown (e.g. X,T). It should be noted that if the teacher has used any part of a module then an "X" or "T" is given.

Table 2: Summary of PAC Module Use By School

School	Motion	PC-Solve	Yellow light	SimCity	Sound	Social Studies	ITS	Maglev	Bridge Builder
Co. School 1	X				X			X	X
Co. School 1	X				X				
Co. School 3	X				X				
Md. School 1	X			X	X				
Md. School 2	T	T		X				X	
Md. School 3	X	X			X			X	X
NM School 1	X,T							X	
NM School 2	X			X	T			X	X
NM School 3	X,T		T	T			T	X	X
NM School 4	X		F	X	X			X	F
Va. School 1				X	X	X			X
Va. School 2		X		X				X	
Va. School 3	X				X			X	F
Va. School 4	X			X	X				X
W.Va. School 1		T		T					
W.Va. School 2	X	X		X				X	F

Generally the Maglev module had the greatest usage, followed by the sound and motion fundamentals modules. SimCity and BridgeBuilder were used in specialized applications, usually in the form of a workstation. PC-Solve, the yellow light problem, and the ITS module were lacking; the opinions stated by the volunteers and teachers generally match Table 2 for these three modules (although a couple of persons did find the yellow-light problem useful). The one exception, however, is the social studies/town meeting activity: while most teachers did not use it, the one who did spoke highly of it and other teachers suggested that a town meeting module be added to the PAC, indicating a lack of awareness of the module but not a problem with it per se.

While Table 2 gives a snapshot of how PAC modules are used in the cases when the PAC is opened at all, this summary information does not provide insight into why or how PAC modules are used. Before delving deeper into these PAC modules, it is critical to first understand the setting in which the PAC is employed.

What is the Classroom Environment?

The school environment – the physical surroundings, the types of people involved, the institutional setting, and the relationship of the PAC to other aids, curricula, and educational requirements – significantly affect how the PAC is used. These findings apply to many educational aids besides the PAC, and they directly affect its probability of being embraced with open arms or relegated to a corner. Variation in how the schools in Appendix D approach the PAC does not obviate the need for future PAC designers to understand common threads:

The PAC is not the focus in the classroom. There is not a single school that was observed by the interviewers where the “PAC” is the centerpiece. Although volunteers and TRAC regional centers will naturally speak of the PAC as a unit, it is just one of many resources available to teachers. This was borne out by the fact that many students, even those that had been exposed to the PAC, did not recognize the words “PAC” or “TRAC” but did recall specific transportation-related activities. Hence, aspects of the program such as the large black box containing the equipment or specific titles (e.g. “motion fundamentals”) often do not carry a lot of meaning in themselves. Instead, the PAC is a resource that, if it is used at all, might supplement regular courses.

The PAC competes directly against other educational aids with which teachers have more experience. As such, TRAC needs to consider competitive advantages enjoyed by these other companies. Examples include technical support, ease of ordering, rapid shipping, updates for lessons, tight integration of lessons with materials, strong classroom presence, and incentives to modify experiments and provide feedback to the company.

There is fierce competition for teachers’ classroom time and planning time. Teachers are increasingly required to devote their free time to preparation of course material, even for activities provided by the school. There is variation in teachers’ willingness to use this free time for school-related work.

Links between schools and outside organizations are not uncommon. TRAC is not the only player in the schools; formal relationships may exist with educational institutions (such as other high schools or community colleges) or businesses (monetary donations, equipment donations, or partnerships where companies indicate what prospective employees should know). While teachers may appreciate the PAC, the act of donating a piece of equipment to a school does not place a state DOT in a unique situation.

There are technologies besides the IBM-based PC that are becoming common in the classroom. One of the biggest is graphing calculators along with the CBL (calculator based labs). In upper level classes they are available to all students; in at least one state graphing calculators are available to all high school students. Macintosh computers are common in some schools, and the number of computers varies greatly.

Career orientation is becoming a priority. Principals and teachers in Colorado, for example, cited the relevance of the “school-to-career” program where skills that are appropriate in the workplace are emphasized in high school. Other teachers specifically mentioned the need for students to be able to use their classroom experience in search of gainful employment, although the prescribed method varied. One West Virginia representative, for example, pointed out that more academic classes such as mathematics needed career examples, whereas a principal from New Mexico argued that vocational subjects such as automobile repair needed to be covered in high school. Interdisciplinary studies are becoming more prevalent.

Students’ abilities are diverse. In consideration of a program that runs from 7^{th} –12^{th} grade, there are a wide range of student capabilities, foci, attention spans, and methods of learning: some students are auditory learners (reacting well to lectures), others are visually oriented, and still others learn by direct manipulation of objects. Teachers value programs that address all learning styles. Even within a specific grade level there is variation. This is especially true in terms of reading levels and the ability to work independently.

Teachers' knowledge of the PAC and their respective subject areas vary. Some teachers receive extensive PAC training over a three-day period, whereas others may have an annual one-day course, and still others have no training. Some teachers have an extensive background in a particular subject but crossover occurs (e.g. English teacher leads. There is not a standard "TRAC teacher". While many noted that the force probes and motion detectors were too sensitive, one experienced physics teacher indicated such a statement is "ridiculous"! Instead, he attributed problems with the probes to poor experimental technique on behalf of those making such a statement. Attitudes toward the computer program SimCity exemplify this diversity: some teachers are comfortable with SimCity as a station in their classroom whereas others simply choose not to use it at all, acknowledging that they do not have the time to determine how to incorporate SimCity in their regular lesson planning.

Levels of volunteer involvement vary. Some volunteers are very active, visiting a school once per week, and even taking responsibility to teach the modules. The norm, however, is closer to visiting a school 3-4 times per year with the teacher taking responsibility for covering the PAC. Experience, age, and comfort level vary as well.

First impressions count. A teacher may formulate an opinion of an entire PAC based on experiences with only a single activity, as observed in the case of the interviewee whose first module was PC-Solve, by far one of the PAC's worst. Hence it is conceivable that any module, selected at random, could represent the quality of the PAC.

What are the Characteristics of an Ideal Educational Activity?

Teachers' and volunteers' experience with numerous types of educational activities proved invaluable when asked to articulate "what makes an educational activity successful." Lessons learned from successful and failed experiments with various non-PAC activities enabled interviewees to indicate what traits make a laboratory or classroom exercise worth repeating. The next generation PAC, therefore, will want to satisfy these constraints in the areas of curricula, materials, packaging, and institutional considerations.

Curricula Characteristics of a Good Educational Activity

Open-ended questions are essential, as these help students think critically and realize that there is not always a single correct answer. For example, asking students "why aren't Maglev trains used here like they are in Europe" makes students contrast land use in Europe and the U.S. While they may be disconcerting, questions such as "what did you find" and "What would you predict" are excellent ways to get students thinking.

It is more important for an activity to be hands on than for the activity to be high tech. When asked which is more important, teachers almost universally responded that hands-on was far more important: low-tech activities that involve cardboard and tape, for example, may be more successful than something that is newer but requires students to do more watching and less doing. The one exception to this view was a teacher who indicated that she felt she could take any activity that was high tech and make it hands on, because of her experience. That teacher did note, however, that in her view a teacher without this confidence would still prefer the hands-on perspective.

Students like competition. One teacher warned that students are competitive in different categories; some want to excel in the hands-on events (e.g. they want the car with the best design) and others want to have the highest test scores. Most teachers noted that competition increased student interest.

Curricula matters as much as materials. Certainly teachers and volunteers provided examples of equipment that hooks students: graphics of SimCity, for example, or the track for Maglev. Yet given a set of materials – even Maglev – it is the way in which the lesson is presented and the way in which a teacher uses it that is critical. Two potential educators, for example, view "Maglev" as being too elementary for even 8th graders yet suitable for AP physics students, respectively. The reason for this disparity is in how the materials are applied. This should translate into an emphasis on curriculum rather than on materials alone.

Activities need a clearly defined purpose. Open-ended questions and activities are excellent, but students need to know why they are doing something. Ordering students to take measurements is not sufficient; instead there must be a reason for performing a task that students understand at the outset of the lab, such as determining the surface area in a room so that one can assess painting costs so that one can ultimately determine whether it is more cost effective to construct a new school or ship students to an older one requiring rehabilitation. When the students understand what they are doing, they are eager to solve problems that arise. For example, one teacher noted that his students worked to solve an equipment problem (the Maglev track strips were not connecting well) rather than giving up because the students could see the overarching goal of the activity.

Students need a clear frame of reference. Prefacing information such as pictures of different types of bridges (for Bridge Builder) or a description of the use of magnetic levitation for high speed trains overseas (for Maglev) is necessary for students to clearly understand the real-world implication of the PAC activities.

Schools are increasingly desiring cross-curricular activities. If TRAC could integrate topics such as technology or mathematics, or if single activities could satisfy several education standards, then the PAC will be more attractive to schools because of this multidisciplinary focus. Improving reading levels, for example, will help a student's performance not only in English class but also in science classes; in fact, one principal noted that weaknesses in reading, writing, and critical thinking skills are what impede students in a physical science course.

Ability to target multiple audiences is a selling point. Educators value activities that are flexible enough to be used with students who have different learning styles, different levels of sophistication, or different ages. Although occasionally stated directly by teachers, it is our interpretation that if a teacher finds an activity useful in one setting, then he or she will naturally want to deploy the activity in another setting, especially if the teacher is transferred the following year to another subject or grade level.

Materials Characteristics of a Good Educational Activity

Materials should be technologically current. Many teachers noted that students faulted the PAC for being DOS-based, having poor graphics, and generally being old-fashioned. (A further challenge to impressing students with high-tech is that they expect technologies at school to be as up-to-date as those that they have at home).

Materials should work. Having laboratory equipment that does not function properly can discourage students and intimidate teachers. More than one teacher noted that fear of equipment failure results in teachers being unwilling to incorporate new activities in their classrooms.

Teachers and volunteers want lessons and experiments that are "plug and play." Certainly an ambitious teacher can, given unlimited time, make a good lesson out of just about anything. Yet, if a goal of TRAC is to meet the expectations of both teachers and volunteers, then PAC activities should be easy to get started. Teachers may be new to the classroom, new to the grade level, or new to the subject area. Training for the PAC is sporadic; teachers usually have access to training only once per year but may attend less often than that. Volunteer turnover combined with an average frequency of 3-4 visits per year means that a typical volunteer may not use a PAC that often. In short, a teacher should be able to pick up a PAC module and fairly quickly understand what the module accomplishes, what materials are required, and how the PAC can relate to the appropriate state standard of learning within the appropriate subject area. All background information and technical manuals should be included in one location for the module.

Packaging Characteristics of a Good Educational Activity

Teachers and volunteers want a PAC that can be compartmentalized by module. Teachers do not use all of the modules and they also want more of some types of materials, such as more copies of the Bridge Builder software and no copies of the PC-Solve software. In this sense, the PAC needs to be offered as a set of discrete modules and activities, with teachers having the option to acquire all, some, none, or multiple sets of the activities.

Teachers and volunteers want a PAC that can be compartmentalized by material. Some teachers may elect to procure materials on their own, such as Styrofoam and Popsicle sticks; others like the idea of receiving everything in a ready-to-go packet. Since states and schools have varying procurement procedures, this should be an option; e.g. a teacher could acquire the curricula for a module from TRAC but purchase the materials elsewhere if so desired.

SOL linkage to the activity is becoming crucial. Some teachers noted they did not have to worry about standards of learning because they weren't applicable for the subject area or because students do not have to pass a particular test at this stage, leaving teachers free to focus on the needs of their students. Still other teachers pointed out that they could look at a PAC and determine independently how the module could (or could not) accommodate an SOL. Yet a substantial portion of the teachers noted that they themselves or their colleagues would very much like to have, in the manual, a statement about which SOLs were covered by the module. At least one teacher mentioned that he needs to do an activity before he can truly know whether or not it will cover the SOL that he hopes will be addressed. Others felt that there was so much pressure to teach the SOLs that they had little time for "extra" material, especially labs.

Institutional Characteristics of a Good Educational Activity

Teachers and schools want technical support and frequent access. One volunteer director noted the need for the ability to order PACs anytime (rather than only at certain times of the year). Teachers and principals both have indicated the need for technical support. Although technical support is available, it is passive in nature: the teacher has to initiate the contact. More active contacts with support personnel may be needed for some teachers.

Teachers want aids that come with supporting curriculum <u>and</u> educator input. Several teachers thought there was no educator involvement with the PAC in terms of curriculum development and the structure of the manuals. Others noted that some of the experiments and software simply do not work. This underscores a fundamental misconception regarding the PAC: while a teacher may well be grateful for the materials, there needs to be a well-conceived, structured manner in which the PAC is incorporated into regular lesson planning; otherwise the PAC is simply in the category with the large number of other unsupported educational resources that are available.

Cooperation with educators, both in practice and institutionally, is beneficial. One TRAC director pointed out that a formal arrangement with his state's Department of Education (DOE) has discrete benefits:

- teachers are encouraged to attend training for the PAC because DOE pays their salaries,
- in that training session, the DOE technology coordinator showed how the state standards of learning could be accomplished through the various PAC modules,
- PAC recipients were provided with a supplementary module (a cube experiment that uses the index cards to demonstrate the principles of forces in physics) which was quite useful, and
- educationally based funding sources are available for the PACs, such as the "school to work" program. In fact, the schools own the equipment, reducing the DOT's level of monitoring.

One criticism of the PAC modules was that they were not designed with educator involvement, in terms of considering what materials they use, how they are presented to students, and their use of SOLs.

How is the PAC Used in the Classroom?

The way in which the PAC is employed in schools sheds some light on how well it meets teachers' criteria for being an ideal educational activity. While the original designers may have had the intention of making the PAC a self-contained collection of transportation-related experiments that would be used as presented, the interview syntheses reflect how teachers use the PAC and how they and volunteers may improve the PAC modules.

Some teachers may cannibalize the PAC for its component parts. For example, a teacher may have an activity from another source that works well but that requires the use of force probes for a calculator based lab. In this case, the teacher may borrow the probes from the PAC for use with another CBL experiment.

Some teachers will use ideas from the PAC but not the modules. One teacher did not do any of the actual PAC activities per se. He borrowed materials from the PAC for use with other activities and he had his students conduct research, write a transportation-related paper, and make a presentation. For ideas on transportation topics, that teacher used the PAC manuals as a resource; in fact, one of his first recommendations during the interview was that new transportation topics be generated that would be suitable for future papers.

Very few teachers will use experiments in their entirety. There are occasions where a teacher may pick a couple of activities (e.g. Maglev) and make diligent use of the equipment and the curriculum. In such an instance, the teacher has to wade through the large box of PAC materials and determine how to link these with the curriculum.

Some activities are used as a workstation. Instead of performing a demonstration in front of the entire class, teachers often use the PAC as one of several stations simultaneously, necessitating that other workstations of similar duration be devised . Other teachers use the PAC as an extra-credit activity (e.g. many teachers use SimCity as a reward for students who finish their regular work early).

Teachers are not aware of all of the capabilities of the PAC. For example, two teachers recommended a new module involving role playing for the decision of whether a town should have a bridge. It does not seem that they were aware of the fact that this type of idea is covered under the town meeting activity in the social studies module.

Teachers and volunteers have lots of implemented and potential PAC ideas. Visits to the schools revealed diverse examples of actual improvements to the PAC materials and curricula.

- In one school where the volunteers teach the modules, they substantially changed the force probe activities such that students learned how this knowledge is used to design crash attenuators.

- One volunteer pointed out that a real-life problem that he faces daily (allocating personnel to snowplows) has strong multidisciplinary possibilities at lower and higher grade levels.

- In one intermediate school teachers are already working in a cross-curricular environment, coordinating math, science, English and social studies lessons. Over time these teachers may have insights into how the current PAC activities may be better presented as an interdisciplinary tool.

- Another teacher assigned his students transportation research papers and presentations and made examples available to the investigators. This should interest the several interviewees who intend to have students conduct research.

Some teachers, volunteers, and students are willing to improve the curricula! One school indicated is rewriting every module in a format suitable for use in a technology lab. Some teachers are willing to have their students work to improve the PAC activities; one teacher asked his students to redo the yellow light problem as a C++ assignment while another teacher and her students indicated a willingness to improve the momentum activity.

Volunteer time requires more than time spent at a school. With the current PAC, the actual time spent at a school may reflect only a portion of the volunteer's commitment. Time must also be spent contacting teachers, preparing a lesson (or what will be said to the students), obtaining necessary equipment or supplies, or making logistical arrangements. In one case, the volunteers noted that the District Engineer gives them time not just to visit the schools but for preparation and training. This is not the norm: one volunteer noted that she has to spend her own time on PAC preparation. Rarely (if ever) is the PAC at the volunteer's home or place of employment.

Responsibility for PAC implementation varies. Not all teachers view it as their responsibility to create an experiment once they are given the PAC materials, while some volunteers do view this as the teacher's job. There is a potential for this actual task – determining how to tailor the PAC activity to the need of the classroom – to not be accomplished. This illustrates that simply giving a PAC to a teacher with an eight-hour training course is not always sufficient. (Of course this task is accomplished in many instances, as explained in the interviews, by both teachers and volunteers.) Note that acquisition of the PAC is initiated in some instances by teachers rather than DOTs.

What Are the Strengths of TRAC and the PAC?

Consideration of how teachers use the PAC in light of what they need in the classroom suggest several strengths of both the PAC and the TRAC program as compared to other educational activities.

A PAC strength is the hands-on activities. The success stories involve modules where the students did the work themselves, such as building Maglev cars or doing transportation-related research. Because the PAC contains actual items that students can do, rather than texts that simply describe what others do, the PAC differs favorably from lecture-based courses or those involving extensive reading.

A PAC strength is its career emphasis. Teachers pointed out that some PAC modules did show students a particular career in which this material can be applied. This point of view is not unanimous by teacher or module; some modules are closer to pure physics experiments than to career exploration. Teachers and principals, however, expressed a need for career oriented programs and TRAC could fill this niche, thereby becoming more attractive.

A PAC strength is visualization; students understand a graph or "see" momentum rather than only reading a description. The PAC builds on experience to promote understanding of what would otherwise be abstract concepts.

The PAC modules reflect goals that teachers and volunteers find worthwhile in spite of equipment failures and flawed curricula. The software package PC-Solve was almost universally disliked and found to be useless and the motion detectors usually did not work properly, but teachers and volunteers liked the concept of teaching students intuitively and by experience what a graph means. The ITS module is viewed as boring, but the idea of explaining ITS as a complement to roadway construction is noteworthy. Some of the original goals behind the PAC were well founded, but to achieve those goals more involvement with educators and the classroom is required.

The presence of the volunteer sets the PAC apart from other educational aids. One of the most surprising findings is the contrast between the PAC and the volunteer; in almost all instances when the volunteer was active in the program, he or she was more important than the PAC. There are lots of other educational activities available to teachers, but very few of these activities come with a real-live engineer or professional. In one case, volunteers visit a school once per week and actively teach lessons that otherwise would not be taught; in this instance the volunteers and supporting DOT staff play a substantial role in improving the quality of education for an underfunded school.

A PAC's strength is its tie to the real world. Volunteers convey material not understood in print. Students need to have seen, experienced, or heard about the topic for it to be relevant to them. If they've never seen a Maglev train or a truck runoff ramp, they may not relate as well to those PAC activities. Even if they have, describing the topics in transportation (e.g. bridges) beforehand makes them real and allows the volunteer to relate the activity to his or her job. Additionally, the teachers and students both benefit from a change of presentation type and style. Volunteers are in a unique position to relate career and local events to the classroom.

What are the Weaknesses of TRAC and the PAC?

Complaints from teachers, volunteers, students, and principals indicate what next generation PAC designers should address. These problems occur in the PAC modules and the administration of the TRAC program.

PAC Module Weaknesses

PAC materials often fail to work properly. When an activity is undertaken, equipment failings are common. They may impact on the activities in one of several ways:

- *the activity is ruined*. A teacher wishes to use a probe to measure force, and compare it to the expression “mass•acceleration”, but the probe readings are so inaccurate that the data collected do not illustrate the theory being taught, and the teacher’s (or volunteer’s) credibility is weakened. Many interviewees mentioned that other teachers are hesitant to use untried activities for fear they will fail, putting the teacher in an embarrassing situation and losing students’ interest.

- *the activity requires substantial modification beyond what is recommended in the PAC*. An experienced teacher may realize a design weakness and make changes. For instance, one teacher had the foresight to add C-clamps to the probes in order to hold them in place.

- *the activity requires minor modification*. One example is probes that work only with recalibration, in which case the teacher (or bright students) must be available to keep the materials working.

The current modules require substantial preparation time, tinkering, training, or some combination thereof. Teachers and volunteers expressed an interest for “plug and play” materials but usually noted that the PAC requires a substantial time investment. Teachers’ attitudes varied towards training: one teacher indicated he would use a module only if he had training, while another noted that even a three day course was not enough. Volunteers especially articulated the view that one must do the modules very often or one forgets what is accomplished during training. (One engineer attributed part of the difficulty of the yellow light problem to the fact that he did the module once a year as opposed to the TRAC trainer who probably has done the module 200 times.)

While the manuals are sometimes used as is, they are also either modified or ignored. There are two schools of thought regarding the manuals: some teachers stated that the manuals did not have major problems, noting that the manuals are a source of ideas and that one can follow what is happening. Other teachers pointed out problems with the student manuals, the instructor manuals, or both: the lack of pictures and graphs, the lack of troubleshooting tips, the similarity between the teacher version and the student version, the fact that manuals are not self-contained for using the equipment with the appropriate lesson, the reading level being too high for some students, the need for more information, and most tellingly, the apparent lack of educator involvement in the actual lesson plans.

The step-by-step procedure in the manuals needs more flexibility. Many of the manuals’ instructions are written such that there is just one right answer for each of many sequential steps; equipment failure thus ruins the lab.

Currently the PAC is an undefined and uncomfortable mixture of a demonstration and a hands-on activity. If one considers the PAC as an ensemble of lessons, it is not clear to teachers or volunteers whether the PAC represents something that the teacher does in front of the class or gives to the students to accomplish. Certainly teachers who are so motivated take the time to determine how to use the PAC, but its application is not clear at the outset.

It is unanimous that a major weakness of the PAC is its inability to involve all students simultaneously. One of the most widespread complaints has been that having a single set of materials for a group of 20 students is insufficient. Different solutions were suggested, such as using the PC as a workstation, doing a demonstration, letting schools purchase multiple sets of certain modules, using CBLs, and using a video monitor, but not a single interviewee noted that one can successfully use a single PC or a single set of materials as a hands-on exercise with a large group of students. Even if the teacher uses the PAC module as a workstation, he or she has to find several other activities for simultaneous use. The result is that teachers who do not want this extra effort probably will not use the PAC.

The current PAC represents a narrow aspect of transportation. The PAC seems well designed for an advanced physics course and does not reflect the diversity of transportation careers. One volunteer stated “For a transportation activity the PAC does not have a lot of transportation” noting that types of work that go on in a state DOT (e.g. right of way acquisition, geometric design, capacity analysis, hydraulics studies, safety analyses, environmental consideration, transportation planning, and interacting with the public and elected officials) are not covered by the PAC. Key careers such as economists, landscape architects, archaeologists, attorneys, and human resources specialists, for example, play an important role in transportation yet are not included in the PAC. Just like teacher input is required in order to make the curricula appropriate for the classroom, volunteer input is required to develop lessons that reflect a bit of the transportation field.

The PAC materials do not reflect tools that a transportation professional uses. Materials found in the PAC (such as motion sensors) are not reflective of the materials used in state DOTs (e.g. traffic simulation software, CAD, construction equipment, and retroreflectometers). Broader transportation topics, such as engine design, are generally not covered at all with the exception of magnetic levitation, which is rarely part of a transportation career.

The PAC gets in the way of volunteers. A recurring theme from volunteers is that PAC modules are an obstacle to making a school visit easier or more appealing. They generally take one of three actions: substantially revise the module, do a different activity altogether, or have a career-oriented question/answer session.

Some PAC modules target a narrow range of students. The PC-Solve software, for example, seems to be written for advanced mathematics or physics students (although some interviewees noted that its problem was more of a result of the software being tedious). Interestingly, under a "one size fits all" PAC, some teachers felt that it was too advanced for their students and others felt that it was too simple for students at the same grade level. Although some teachers can tailor lessons to any age level or class subject, the PAC modules are not helpful in this regard.

TRAC Program Weaknesses

Teachers often do not know how to obtain technical support. One teacher noted a "disconnect" between the PAC modules' instructions and the equipment instructions, especially when stored in different locations within the PAC. The general 1-800 technical support number is not always used: one teacher called Vernier directly to find that she could recalibrate the probe by simply turning a screw.

Standardization of volunteer activities is lacking. Several teachers mentioned that they had never been contacted by a volunteer or that their volunteer had come a few times and then "disappeared"; additionally, turnover can result as volunteers change jobs. Since the presence of the volunteer is the most distinct feature of TRAC, compared to other educational aids, ensuring continued volunteer support is essential.

No interviewees knew of methods already in place to quantify TRAC's benefit. Several interviewees mentioned work that is underway to do this measurement, ranging from surveys to follow-up interviews after graduation, and several interviewees mentioned the need to assess TRAC quantitatively.

TRAC does not have a unifying goal or one that can be measured. Many persons readily cited broad goals such as improved public relations, getting students interested in some aspect of school (transportation, civil engineering, math and science, or the broader aspects of transportation such as accounting and public relations), and improving the quality of the work force. Some of the volunteers expressed confusion concerning the stated TRAC objectives.

It is a challenge to keep PAC materials updated and teachers informed. Often teachers had just acquired a PAC and there were some cases where there had been little communication between the teacher and the TRAC program. The interviews would suggest there seems to be no specified source for update information.

RELEVANT THEMES FROM THE LITERATURE

There are articles, advertisements, and experiences of other outreach programs addressing six objectives directly relevant to designing a new educational activity: (1) broad theories of learning, (2) specific teacher paradigms, (3) products available from suppliers of educational materials, (4) specific examples of low-cost experiments, (5) the perception of what "transportation" means, and (6) longevity as a goal for the TRAC program. Many of the concepts to which interviewees alluded are supported by these sources.

Broad Theories of Learning

Three schools of thought have dominated science teaching in the last 50 years including developmentalism, behaviorism, and cognitive science (constructivism).(*8*,*9*) Developmentalism holds that there are age- or maturity-related restrictions on what students can learn.(*10*,*11*) The behaviorist tradition emphasized the role of reinforcement in learning, teaching skills in a stepwise fashion, with simpler skills building to more complicated ones. Behaviorist classrooms were known for carefully constructed instructional programs with no age limits imposed.(*12*) The cognitive-based constructivist tradition emphasizes that science learning must build on the student's existing knowledge, recognizing the significance of students' previous learning (preconceptions) and the power of learning by doing. Under these theories, "the learner makes sense of experience by actively constructing meaning,"(*9*) hence the current popular label of constructivism. The motivation for this active construction is the conflict between the student's current models of the world and new experiences that do not fit the old models. Constructivism has become the most widely supported learning model for science instruction among contemporary science educators(*13*,*14*) and is a theme in the national science standards as well.

With regard to developing activities and constructing curricula for TRAC, a constructivist inquiry/problem solving approach allows TRAC to make transportation more accessible and understandable to students.(*9*,*15*)

A Teaching and Learning Model for TRAC Development

The origins of constructivism date back to the time of the Greeks, and the theories of several notable psychologists and educational researchers, such as Dewey and Piaget, fall comfortably into the realm of constructivism.(*16*,*17*) This philosophy fits especially well into science learning because science is constantly changing. In order to stay current, ". . .things must be learned only to be unlearned again or, more likely, to be corrected." (*18*, p. 4) This is the basis for constructivism. Science learning now continues well after graduation. In order to make informed, real world decisions as adults, students must continue to compare their previous models of the world with new information to create new models, amending the way they perceive scientific fact.(*19*)

Using constructivist principles has been advocated for a number of years, however, this teaching and learning model offers new challenges for more lecture-driven (i.e., traditional) teachers. The emphasis on identification of students' existing understanding of the topic to be studied and the focus on inquiry and student participation in problem solving events is time consuming and requires a broader base of pedagogical strategies. Students' understanding prior to instruction on a topic is of great significance and is referred to as the students' "preconceptions." To design effective instruction, preconceptions and their origins are used to modify instructional design as circumstances dictate. These preconceptions often conflict with current understanding of science and, though "transparent" to teachers, are often held as nearly immutable "laws" within the minds of the students. It has been shown that students can compartmentalize what they use in everyday life from what they learn in school.(*20*) Hence the students have one mindset for school and another in their own lives — as one might imagine, the students nearly always fall back to their personal interpretations once they leave the classroom.

These student held theories of how the world works, which are frequently in conflict with the accepted scientific view, are what the student brings to the class, and what the teacher seeks to amend through exposing the student to examples that do not fit the alternate conception.(*21*) This can be done in three stages:(*22*)

(1) The *exposing event* – that students interpret using their own conception of the world,

(2) The *discrepant event* – which created the conflict between the observation and the students' alternate conception, and

(3) The *resolution phase* – in which the students articulate and elaborate on the desired, new conception through application in unique or extended circumstances based on the previous exposing and discrepant events.

As noted later, this is the structure that some of the teachers interviewed used in their classrooms. Clearly, it is important for teachers to understand and be enabled to help learners actively construct, or generate, meaning from sensory (cognitive and hands-on) input — no one else can do it for them.(*9*) Furthermore, this must be accomplished from the beginning point of the *students' current understandings,* because to ignore the power of their preconceptions is to reduce possibilities for maximized learning and retention.

Researchers have documented alternative conceptions for such diverse topics as “vectors, kinematics, dynamics (including friction, gravity, energy, momentum, and pressure), heat and temperature, electricity, light, density (including mass and volume), the particulate theory of matter, the earth as a cosmic body, evolution, heredity, the circulatory system, and life.”(*23*) It has also been noted that students’ alternate conceptions and models of the world are strongly influenced by their experiences and the culture they live in, perhaps even more so than through their traditional schooling.(*24*) Both documented alternate conceptions of various scientific specialties and the students’ cultural background should be taken into consideration when designing TRAC modules.

This last point is especially important in light of the fact that the National Committee on Science Education Standards and Assessment has included as one of their goals to educate students to use appropriate scientific processes and principles in making personal decisions. The Committee also asserts that, “inquiry into authentic questions generated by students’ experiences is the central strategy of teaching science.”(*25*) Thus, teaching that is relevant to a student's world and that can be used on an ongoing basis is essential for TRAC modules.

In addition, given constructivist thinking, the new models presented should be internally consistent and intelligible, plausible, and fruitful, i.e. there needs to be some good reason why the student should work to incorporate the new model into the students’ mental structure of understanding. Models that improve predictive power or explain more of the variance in the real world are more likely to be worth students’ intellectual effort. Thus, the usefulness of that new information needs to be emphasized in the TRAC curriculum. The eventual result is the replacement of students’ inadequate or erroneous preconceptions with an accurate and contemporary understandings of the science and engineering involved in the subject of study.

The Underlying Cognitive Basis for TRAC Development

Contemporary research on understanding (cognition) indicates that unconscious mental structures underlie all human knowledge.(*15*) The organization of knowledge has a direct impact on the initial learning and on knowledge retention. Thus, memory organization is a major factor in future performance competence. Studies have shown that with regard to technology education, experts’ recall of newly learned technological information is better than novices’ due to the experts’ possession of a well-developed knowledge structure in which the new learning has a place. (*15*,*26*) This is thought to occur because knowledge structures:

- enable the recipient to prioritize, affecting the amount of attention given each piece of information,
- create a frame of reference in which knowledge can be stored or anchored,
- allow for easier retrieval from memory, and
- interact with new information to create a combination of new and old knowledge structures.(*27*)

By presenting simple conceptual diagrams of what is being taught, teachers can help generate sensible and accurate knowledge structures necessary to promote understanding and retention.(*28*) Also, by explaining the purpose of the activity and relating it to areas within the students’ frame of reference, teachers can make the most effective use of students’ existing knowledge structures.

This cognitive-based approach to instruction creates more “expert-like” behavior among less experienced problem solvers. Studies have shown that experts are able to isolate the important parts of a problem by using their existing knowledge and can concentrate their attention there. They process only the information needed to address that part of the problem at that time. Novices do not make these distinctions and cannot discriminate between relevant and irrelevant knowledge.(*29*) Experts also analyze the problem more before beginning work on a solution, and are not dependent on a single solution.(*30*) Researchers have suggested the use of metacognition to deal with these differences. Metacognition is the students’ awareness of their own thinking processes, the planning that goes on before beginning a mental activity, and the monitoring of their mental performance afterward. Through direct instruction, students can be introduced to the fundamentals of problem solving, and through self-evaluation and application, refine these skills. This self-monitoring is sometimes done by encouraging students to think out loud, expressing the steps they are taking to address a problem.(*31*) Also, reciprocal teaching may be used, where students ask questions of other students and taking the role of the teachers, summarize material, predicting what comes next.

Another issue considered in cognitive science is the context of learning and the transfer of knowledge from one situation to another. The context in which something is learned affects the indexing of information, which affects how and when it is most easily retrieved. Unfortunately, the context of work and other real life problems is very different from the context of school. School stresses individual performance, whereas the workplace stresses teamwork. School stresses unaided thinking and recall, whereas the workplace (and the world) stresses using tools and other information found in written resources. Schools instill stand-alone information, while the world stresses linking information to solve problems. In order to transfer to real world settings (including making everyday decisions), TRAC modules should be as closely tied to the real world as possible. However, real world activities are rarely as linear and predictable as most classroom activities. To insure maximum transfer of information and problem solving, TRAC modules should use "flexible, highly active discovery methods rather than lock-step procedural methods." (*15*,p. 40)

Applying Theory and Pedagogy to TRAC Development

Linn and Muilenburg present an example that puts these theories into practice. In terms of heat flow models, students may observe that when comparing a metal object and a wooden, the metal object feels colder, even though both are at room temperature. The elegant molecular-kinetic model, based on the random motion of molecules in a substance, can be taught to explain this observation, but the concept of temperature gets defined in the model as a statistical abstraction. This theory, although accurate, removes the notion of temperature from the students' frame of reference and may not be intelligible or appear plausible to the student. Thus, the students are likely to use the molecular-kinetic model primarily in the classroom and to fall back on their own previous models to explain everyday occurrences, concluding that they have "never learned anything useful" in science class.(*32*) This falling back on previous models have been documented to occur even among professional scientists, including mechanical engineers.(*19*)

Instead of the molecular-kinetic model, Linn and Muilenburg recommend teaching the heat flow model, especially to students new to the sciences. This model makes three assumptions: (1) heat energy flows from objects at higher temperatures to objects at lower ones, (2) if more heat enters an object than leaves it, its temperature increases, and (3) heat flows slowly through some materials (thermal insulators), such as Styrofoam. This model is easily understood by students and is more likely to strike them as plausible. It is also easily transferred to real world situations, making it fruitful. In a 1991 study where the heat flow model was reinforced using relevant problems (like how to keep soft drinks cold longer or whether a snow shovel with a metal handle would be more comfortable to use than one with a wooden handle), Linn and Songer found that students who were taught the heat flow model learned more about heat and temperature and solved more problems than those taught the more elegant molecular-kinetic model.(*33*) In addition, eighth graders who were taught the heat flow model were able to generalize this model to the biological concept of diffusion as 10^{th} graders, and were better able to understand the molecular-kinetic model as 12^{th} graders. "Because it is accessible to most students, the heat flow model also empowers students to connect ideas gained in solving personal problems to a model discussed in science class"(*19*)

Thus to benefit from these theories of learning, PAC module designers should consider these concepts:

- Use what students already believe about science along with their observations to build new, more reliable models of the real world. Cultural and experiential backgrounds should be considered, as suggested with New Mexico School 2 in Appendix D.

- Create a knowledge structure for students prior to beginning an activity by using simple, conceptual diagrams of what is to be taught.

- Employ the process of discovery learning (exposure, observation, conflict resolution) when appropriate.

- Directly teach students the various approaches to problem solving and use metacognitive techniques to help them monitor and improve their problem solving abilities. Encourage teamwork and the use of all available tools to solve problems.

- Make the classroom learning environment as much like the real or working world as possible emphasizing inquiry, collaboration, and problem solving.

- Provide students with a good reason to incorporate new knowledge by designing TRAC activities to be useful and by pointing out their usefulness in every day life, and by incorporating the flexible, highly active methods in class.

Specific Teacher Paradigms

As shown in the interviews from Appendix D, teachers have definitive views regarding how students learn, and these paradigms in turn affect how educators design curricula and materials. The literature further explains the beliefs put forth by educators.

One theme from the interviews and the literature is *how students acquire knowledge in a laboratory exercise via the three step learning cycle.* Recall the physics teacher who firmly believed that a good lab has three components: an exploratory concept, an activity to flesh out the concept, and an application to a new situation. That teacher had argued that a poor lab would mix these steps (e.g. students might be asked to explain why slippery asphalt causes crashes before understanding what exactly is the coefficient of friction.) The University of Dallas maintains a demonstration of this three step learning cycle with the example of position versus time graphs, a similar notion to what is in the PAC.*(*34*) Methods for accomplishing the lab in each of the three stages are presented; in the exploratory phase, for example, students learn that the slope of the line reflecting distance versus time is affected by their walking speed; in the concept phase students try to duplicate the presented graph, and in the applications phase students try to explain how new shapes (e.g. a horizontal line) can be created. In all, a series of about 20 questions are presented, illustrating how a teacher should lead students through the activity. By comparison, for a similar activity, the PAC manuals offer far less guidance for the thought process that students should undertake or that teachers should use to guide the students. Aside from twice asking students to "discuss" what happens, only a single question is presented in the students' manual.

A second theme from the interviews is that teachers wan *to teach students to be able to "think" rather than just memorize facts*. Often teachers presented different ideals, such as recognizing careers that relate to the subject at hand, encouraging the student to formulate questions of interest and ultimately their own hypotheses which would be tested, and requiring students to create their own solutions before acquiring them from a textbook. A prime example of the latter is a teacher who wanted her students to build Maglev cars before being given guidance on key design principles, such as aerodynamics and friction. Under this teacher's constructionist views, suppose an "old" way of thinking is that the force a vehicle must absorb in a crash is linearly proportionate to its velocity – e.g., one might originally suppose that a crash at 20 mph results in only twice as much force being absorbed by the vehicle as a crash at 10 mph. The truth, however, is that a crash at 20 mph requires that four times as much force be absorbed by the vehicle. One may observe this truth through either a derivation of Newton's Laws or an examination of crash

*The three-step cycle is based on how people learn, which enriches the meaning of the exploratory phase: students are directly confronted with the problem and begin to see what is needed to solve the problem. This creation of the desire to solve a particular problem is the critical element in the exploratory phase; using the above example, a real-world problem facing engineers for which this type of activity is performed is designing walking signals at intersections. Hence in the exploratory phase students might be told the following: "You as a driver want a green light for as long as possible: you certainly know what it is like to be stuck in traffic needlessly! Yet you as a pedestrian want enough time to cross the street with a walk button: you certainly have had to deal with crazy drivers! So how do you make sure pedestrians have sufficient time to traverse the intersection without making drivers wait too long?" Then, after some discussion, one introduces time-space diagrams as an instrument used by engineers to solve this problem.

injury rates at different speeds. Constructionism postulates that students would learn this truth – that the absorbing force is proportional to the square of the initial velocity in this instance – because of the conflict between student's old ways of thinking and these new observations.

A third theme is that teachers stressed the need for *open-ended questions with more than one right answer*, such as "why are Maglev trains used in Europe but not in the United States?" Formulation of such questions is an important part of the PAC curriculum, especially for some of the transportation-related policy issues that may become a focus for a structured classroom debate. The literature offers principles and a process for formulating a good guiding question, making sure to that questions are succinct, non-judgmental, focused, and thought-provoking.(*35*) Specific techniques are suggested, such as using the six w-words (who, what, when, where, why, and how) and beginning with several candidate questions and refining the list by seeing which questions are more encompassing. These techniques would be of benefit to future PAC designers as they write curricula that satisfy teacher's desires to have useful open-ended questions.

A fourth theme that emerged from the interviews is emphasis on *cross-curricular activities*. Like the "open-ended question", though, this is not viewed as a panacea; some structure is required to take advantage of this approach, and it may require some extra work. TRAC can position itself as a resource that helps teachers with cross-curricular activities in a real-world format. The volunteer is the major component, as that person can illustrate, for example, why communication skills and technical skills are needed by a single person in a career. Yet there are also ways in which the PAC can be organized so that its activities can be used by multiple disciplines and coordinated. While "interdisciplinary" approaches have been suggested, the literature suggests at least nine variations on how curriculum may be integrated across multiple subjects.(*36*) One example is to take a topic that grabs students' interest – e.g. demolitions – and then relate various lessons to that topic; in this case, for instance, one could analyze the physics of explosions as well as the engineering question of when it is more cost-effective to refurbish a bridge or to replace it entirely. Yet another means of integrating curricula is the "shared" model, where a particular subject overlaps (e.g. in the case of the PAC, a physics course may use sensors to measure speed whereas a pre-engineering course teaches how a sensor functions).

Products Available from Suppliers of Educational Materials

Teachers often mentioned instructional aids that they had acquired in addition to the PAC. A better understanding of what is needed by schools can be gleaned from examining these products offered by private companies. Mention of these commercial suppliers is not an endorsement but is done to provide examples of where additional information may be obtained. These products usually include both equipment (e.g. hardware, software, renewable supplies, etc.) and curricula or lessons for how to use the equipment in the classroom.

Generally, a wide range of hands-on products is offered in the diverse subject areas of computer graphics, biology, robotics, communications systems, and other technology areas. For example, one supplier offers computer aided drafting curricula, an "earthquake simulator" where students design a structure and test its resiliency, and a hydraulics systems module that teaches applications such as aircraft suspensions and braking systems.(*37*) It may also be appropriate to examine suppliers of technology equipment and curricula, since frequently the PAC modules are used as a "workstation" with other activities. These suppliers offer diverse technology/vocational curricula such as aerodynamics, electronic media, or architectural design.(*38*) If the PAC were as one workstation with these other products, it would be prudent to know what they were so that the PAC did not duplicate them.

It should also be noted that technologies exist which are capable of yielding students a data set with which they may do traditional types of analysis. For example, one interviewee had cited a particular laserdisc, entitled "Physics of Sport", where a frame-by-frame review allows students to compute physics concepts such as speed, momentum, and energy. A supplier of these types of laserdiscs offers not only the software but also suggested curricula, in the form of a teacher's guide and a student's guide.(*39*) As another example closer to the PAC's "town meeting", the same supplier offers on CD-ROM a set of lessons containing dissenting interviews with citizens, legislators, and field personnel; the students then use these views along with accompanying data and background material to form their own opinions on topics such as "using animals in research" or "associating behavior with genetics." While the compact disc has a biology focus, there is the potential to use this technology to supplement the future PAC's town meeting concept for situations when a teacher is not able to develop a good topic of discussion for that module. Alternatively the CD could focus on national transportation issues. The Center for Occupational Research and Development offers a variety of curricula, two notable examples available on CD and geared toward grades 9-12 use mathematics to manage a toxic spill from a train crash and to put out a forest fire (using vectors and topography); the CD includes realistic sound effects and news coverage.(*40*)

There exist multiple sources for equipment contained in the current PAC as well: for example, the motion sensor from the current PAC supplier is available as a "sonic ranger" from another supplier; similarly there exist multiple suppliers for force detectors.(*41*) The supplier of much of the current PAC equipment in fact offers complete curricula that make use of calculator based labs (CBLs) in conjunction with motion detectors, force sensors, light sensors, and electrical equipment; examples of these labs include Newton's laws, Ohm's Law, "graph matching", and "impulse and momentum.(*42*) In fact, suppliers of CBLs offer labs as well; for example, one company shows which probes are needed for various labs such as sound waves, pendulums, and projectile motion.(*43*) When standardized equipment such as CBLs are considered, TRAC has the opportunity to use multiple suppliers for identical products, which may be helpful if TRAC finds that one supplier is having trouble meeting the needs of TRAC's customers.

Sources of Low Cost Activities

During the interviews, teachers or volunteers consistently cited examples of low-cost activities that required few materials and minimum preparation time. Often students were quite intrigued with these examples, even more so than higher-tech applications. In the PAC, for example, students enjoyed using the Styrofoam, paper clips, and tape to design the fastest or furthest-traveling car; when the PAC was not used, teachers recalled popular contests such as the "egg drop" or the construction of a chair solely out of cardboard that could sustain a 200 pound teacher". These activities are not restricted to younger students; a hands-on "isotope pennies" activity is used in one Colorado high school science class where students devise their own hypothesis to determine the number and type of pennies in a can based on their atomic weights.

TRAC may not want to duplicate these activities, but it may want to either put a new twist on them that focuses on transportation or use them as a source of ideas for the next generation PAC. In addition to the specific examples cited by educators, there are texts, Websites, and institutions that focus on how to use low-cost materials to attract students' attention. As an illustration, the National Association of Biology Teachers offers laboratory exercises that require inexpensive materials and which contain open-ended questions, two key elements desired by TRAC teachers.(*44*)

There are examples that are also specific to transportation. One is the San Francisco Exploratorium, which has on-line and in printed form suggestions for basic science experiments ranging from elementary school up through high school. A vector-based lab is presented; it requires a simple walking toy (prices given as between 50 cents and $2.00) where students compute the amount of force required to pull the toy after accounting for the fact that only the horizontal component is relevant.(*45*) The American Association of Physics co-sponsors a publication that relates physics to several real-world phenomena including the yellow-light problem, braking and stopping distance, and collision impacts; what would be of use to TRAC is the text's suggestion of using a spreadsheet to accomplish some of the physics computations.(*46*) Additionally the Web has resources that are used directly in education; for example, Rice University has a site that explains how real-time traffic information available from a traffic management system may be used to learn how to compute rates of speed and resultant travel times.(*47*) There are also texts that focus on the broader aspects of transportation; one of these is written by the American Chemical Society and relates transportation needs to energy, technology, and planning.(*48*) The value of this transportation systems module is twofold: it suggests a fairly realistic methodology for analyzing a school's transportation system with activities students can accomplish, such as conducting surveys, and it also illustrates how a teacher's guide should differ from a student's guide, with the former having teaching tips, expected problem areas, and estimates of how long each task should take in the classroom.(*49*)

The results of the student interviews indicate that students may provide excellent ideas for improvements to the modules and new activities. Certainly, some of these results are not necessarily feasible without an enormous amount of money, and other suggestions were presented (we think!) in an attempt to be humorous. One can find, however, some suggestions for new modules. One example is the use of accident data, taken from the Department of Motor Vehicles or equivalent, that could be analyzed by students to objectively find trends in crash rates. (This can be expanded for more advanced students to find geometric design flaws based on crash rates, although more work would be required.). Other examples were presented that do not tie directly to transportation but do cover students' interest, such as one Algebra I student suggesting that basketball scores, averages, and ranges could fit well within a math class. In one high school technology class at a Maryland high school, a student pointed out the value received from constructing a windmill out of a small generator, wood, and glue.

Perceptions of "What is Transportation?"

The literature can show what kinds of transportation careers are *not* generally known to the public. For example, sources are available which describe well the evolution of transportation modes, especially the role of inventions.(*50*) Other excellent sources are available which outline the role of bridges and their relationship to the transport system, pulling in the need to understand physics and design principles, as well as materials-based experiments such as making concrete.(*51*) Yet volunteers cited in Appendix D highlighted other examples of work that occupy daily responsibilities of a transportation professional – such as communicating with the public, mitigating environmental impacts of a proposed design, or operating traffic control devices and other parts of a TMS – that are not conventionally viewed as transportation. These omissions, in conjunction with suggestions by volunteers and teachers, suggest ideas for future PAC modules.

Longevity as A Goal for the TRAC Program

The investigators became aware of a dated list of educational outreach programs that had been compiled as part of NCHRP TRAC-related work. Experiences with contacting these organizations highlighted a goal for the next generation PAC that the investigators had previously not envisioned: longevity.

A directory of educational outreach activities is shown in a 1993 document that focuses on bringing civil engineering to the classroom. The directory lists public and private-sector organizations who work with schools to interest students in math and science at the K-12 levels and at the college level.(*52*) The programs are stratified by grade level as well as by one of three activity types: making students aware of civil engineering, retaining interested students, and influencing the school curriculum.

Considering only the programs covering the K-12 levels, there are over 200 entries, although a few are duplicative. Each entry names a program, a sponsoring organization and contact person, a target audience, and a one or two sentence description indicating what the program accomplishes. Attempts were made to contact a dozen of these entries.

The directory lists innovative programs from which TRAC may gather some ideas; for example, the American Association for the Advancement of Science's "Science Linkage in the Community Project" has one program where a local chapter trains teen volunteers to teach science to younger students. Another program consists of the state Department of Transportation sending a speaker to a class once during a semester or year, encouraging students to consider DOT work; the DOT then sends the student a birthday card every year so long as they remain interested, and at age 18 the student is sent an application to work for the DOT in the summer. The directory shows other organizations that also have functioning programs such as the American Chemical Society's FACETS (Foundation and Challenges to Encourage Technology Based Science) and the Penn State Youth Writing Project. The fact that these programs are still in operation six years later suggests that they are credible.

A couple of the organizations could not be reached at all, however, even after trying to locate them through directory assistance. Additionally, some persons who could be reached noted that they were not the contact person, that the program had a slightly different focus than what was implied in the directory, or perhaps that the program had changed names. Consequently several phone calls were sometimes necessary to the same organization in order to ascertain that a program was still ongoing.

The contrast between those programs that are still functioning and those programs whose contact personnel had changed or who could not be reached at all offers another goal for TRAC: longevity. By continuing to actively work with state DOTs and DOEs, TRAC can, as time passes, become a reliable educational outreach program. Even though the current PAC has its share of drawbacks and the states have differences of opinion as to what TRAC should accomplish, at least one can fairly easily recognize the TRAC program as usually having a volunteer, a PAC, or both. If over the next five years TRAC can continue to exist, be accessible via the Web, regular mail, electronic mail, and telephone, and represent a true initiative, then it will compare favorably with those organizations that do not remain actively involved with schools.

RELATING STANDARDS OF LEARNING TO THE PAC

One of the recurring themes from the interviews was that state *standards of learning* (SOLs) play an important role in education. This does not mean that educators, students, volunteers, or the authors endorse this practice; rather, educators are viewing SOLs as increasingly relevant in the classroom. In this context, an SOL is a type of knowledge, skill, or information that students of a particular age, grade, or class are supposed to acquire in the classroom. SOLs are also referred to as benchmarks, skills, learning goals, content standards, and curriculum matrices. It is acknowledged that the scope, context, and relevance of an SOL will vary not only by state but also by grade and class.

In order to consider the feasibility of tying the PAC modules to state standards of learning, math and science SOLs from several states were examined. This did not result in a definite linkage of each SOL to each module; however, it gives the reader a flavor for the variation of SOLs by program and subject matter. For example, future PAC designers are likely to ask is "what is the relationship between SOLs from one state to the next? Is an SOL a guideline that can be accomplished in a variety of lessons, or is it a firm standard that requires students to learn a basic fact?" The discussion of SOLs is critical to the PAC; however, the material can become tedious rather quickly. Hence details are relegated to Appendix B.

Appendix B describes the organization of SOLS in mathematics and science for the five states where interviews were conducted: Colorado, Maryland, New Mexico, Virginia, and West Virginia. Rather than simply repeating the SOLs, the Appendix explicitly indicates, as an illustration, how a new PAC module on surveying and geometric design could be related to the mathematics SOLs. Because of their relevance to transportation activities, sample state standards in the areas of social studies and technology are also outlined therein. Finally, national standards show desired trends in teaching; hence these covered in Appendix B. These findings may be summarized across three areas: comparison of math and science SOLs among the states, the role for educators in interpreting the SOLs, and relating future PAC curricula to other SOLs and national trends.

Comparison of Math and Science SOLs

There is overlap within the standards of the five states that were reviewed, with common themes expressed by multiple states. Additionally, the standards are not mutually exclusive by subject: technology, science, mathematics, and social studies benchmarks can, in fact, be tied to a specific activity. For example, multiple states indicate or imply that students should use properties of triangles in a problem-solving context. *Differences in organization* complicate matters and may initially obscure these similarities, but review shows that knowledge of triangles and trigonometric relationships, for example, is still covered, even if states place it under different headings such as "algebraic concepts" versus "geometric concepts."

There are substantive differences in the state SOLs, but the differences are more in emphasis rather than in contradictory information. For example, both the National Research Council and several of the states view the act of scientific inquiry as critical: it is clear, from reading the appropriate texts, that failing to address this skill would seriously undermine a science course regardless of the content. Virginia's SOLs do mention the role of scientific inquiry, both in the prefacing information and for a couple of the courses. Yet if one compares the number of SOLs dedicated to specific content with the number dedicated to general scientific principles of inquiry and investigation, there clearly is more material devoted to content and factual matter in the case of Virginia. This does not mean that different PAC modules should be developed for each state; instead, it may mean the way a PAC module is related to an SOL varies by state.

It is possible to relate a PAC module to these SOLs as is done in Appendix B. This is not difficult to accomplish, but the question of "who" should do this will vary by state. It is probably unrealistic for TRAC National Headquarters to tie each module in the PAC to a specific standard, but there may be room for compromise depending on the popularity of the module and the resources in the particular state's DOE and DOT.

Role of Educators in Interpreting SOLs

Educator involvement regarding SOLs, especially at the outset, is critical for three reasons:

Interpretation of the SOLs requires going beyond what is written. Certainly a non-educator can review standards from different states and make comparisons. Understanding how a school system will implement the SOLs, however, requires an educator's viewpoint. For example, one DOE representative offered a caveat that was not evident from reviewing the documentation: it can suffice, depending on the state and subject matter, to tie a module to a more general SOL (e.g. using critical thinking skills) rather than to a specific benchmark (use switches in a control circuit). Yet in another state it has been said that while meeting broad standards was the original intention, SOL tests are now requiring a strict linkage between curricula and detailed benchmarks. This disparity suggests that DOE representatives from the state in question will need to comment on the most effective level of SOL/PAC linkage. For example, the principal and math teacher from one Colorado high school pointed out that the Bridge Builder module may be used because it meets appropriate standards at several levels:

- the *lab content* standard, since the course must have some amount of laboratory time.
- the *physical science curriculum* standard, since the lab teaches Newton's law and force vectors
- a *specific* standard which requires students to interpret and make a force diagram, and
- a *general* standard which requires one to interpret graphic materials and scientific drawings.

The PAC may be competing against pre-built curricula that drove establishment of the standards. In one state, the technology SOLs actually derive in part from a very detailed (and proprietary) set of curricula that accompanies workstations provided to the school. This is not to say that the PAC cannot have a contribution; in fact, in that particular state, the DOE representative noted that the PAC has a useful niche in showing how academic subjects such as geometry or English can relate to a career. Yet this does show that in such instances, PAC module designers will want to communicate with educators who can explain what is not self-evident from a review of the SOLs: those not covered by a set of readily available educational activities.

It is our belief that the SOLs are in a state of flux – one of the five states surveyed has them in draft form and, more importantly, the teachers noted that the penalty for not meeting the SOLs seems to vary. In Virginia, for example, only 2% of all schools reached an acceptable mark of having 70% of all students pass the SOL tests, which will be necessary for accreditation by 2007.(*53*) The fact that penalties for not meeting SOLs will increase in the future suggests that it is quite possible that SOLs or teaching methods will evolve.

Relating PAC Curricula to Other SOLs and National Trends

The PAC can meet other standards of learning besides those in math and science. Because of volunteers' frequent comments that transportation is a much broader discipline than what is shown in the PAC, SOLs from technology and social studies are also considered. Appendix B illustrates that select current PAC modules, such as the town meeting, and proposed future PAC modules, such as the one of surveying, may also be related to these SOLs. This finding is relevant because it offers the PAC a niche in the schools through other avenues than math or science. The skills taught in these other courses, such as oral communication, writing, and interpreting political systems, are considered an integral part of many transport careers. It is reasonable to consider SOLs in diverse subjects, including English, economics, social studies, technology, math, and science, when devising suitable PAC curricula.

The national standards emphasize trends, skills, or knowledge that educators find desirable. Appendix B lists how three trends from the national standards can be applied to the next generation PAC: demonstrating that science has a real world application, synthesizing information from diverse sources, and focusing on scientific inquiry. The PAC may gain acceptance to schools by exploiting these standards; in particular, the need to make sense of information from multiple sources relates directly to many of the complex social policy decisions faced by DOTs. The example shown in Appendix B of determining whether states "should" mandate that school buses be equipped with seat belts is not an academic exercise but instead arises in public policy debates. The national standards are an excellent resource for detecting what types of learning are being emphasized by educators.

The state standards also emphasize traits educators find desirable. For example, graphing calculators and the use of technology are encouraged in mathematics courses, along with problem solving and applying mathematical reasoning to situations in other disciplines. Hence the state SOLs offer clues as to how volunteers or state trainers may want to present a module.

HINDRANCES TO EVALUATING THE PAC: OBSERVATIONS FROM THE INTERVIEWS

Previous efforts to obtain detailed information regarding PAC usage have been unsuccessful or have not been publicized. The investigators found it difficult to obtain detailed information unless one physically visited each school and allotted several hours to discuss the program with the teacher, principal, students, and volunteers. Rarely could all of these persons be convened in one location or even necessarily on the same day.

A common theme throughout the findings is the need for increased communication between teachers, volunteers, school leaders, and the administrative heads of the organizations affecting TRAC: state Departments of Education and Transportation as well TRAC National headquarters. It is thus worthwhile to consider what impedes this flow of communication. Not all impediments apply to all states but they do indicate that monitoring the TRAC programs are not easy.

It is unlikely that full participation information about the schools is known by a state regional center. It is not the norm for a TRAC regional center to always know the full extent of each school's participation. Possible causes are the fact that teachers are not always readily accessible with the same mode of communication (email, fax, a phone call at home, a phone call to the school, or regular mail will eventually work, but no single mode works with all teachers!), the fact that no TRAC centers have a director whose sole responsibility is TRAC (in fact, most states' directors are doing several other duties besides TRAC), and the fact that a TRAC program has several layers of individuals responsible for its success (DOT management, volunteers, volunteer supervisors, and teachers, not to mention liaisons with state Department of Education or TRAC national headquarters' personnel). While interviewees were candid about the difficulty of keeping track of school participation, examples from the states that were visited highlighted the challenges to knowing who is actively involved in TRAC:

- the initial visitation date for one state had to be rescheduled owing to the fact that the volunteers who were working with the schools could not confirm the dates with school personnel.

- a teacher previously suggested by the TRAC regional director stated to the investigators that he was not planning to participate this year because his students "were not worth it."

- a school described by one director as a center for at-risk youth turned out to be a "magnet" school open to students who wanted to take specialty courses not available in their home schools.

- one state posted on its Website a school no longer involved with TRAC. The state coordinators, though, were aware of that school's lack of participation.

- Unbeknownst to the TRAC regional director, a teacher to whom the PAC had been given rarely used the PAC because her students suffered from severe learning disabilities. She was, however, able to recommend another teacher who was using the PAC.

- in another state whose schools were considered but ultimately not visited, a new TRAC director mentioned that it was difficult to get teachers to return phone calls.

These impediments are not criticisms of states' programs but they do illustrate that even obtaining basic information is difficult, making evaluation of individual and newer PAC modules much harder.

Nomenclature is an obstacle. There are different ways of describing the PAC modules: some differences are semantic (e.g. force probes vs. force "boards"), some are fundamental (e.g. describing a research paper as a PAC activity), and some are not clear (e.g. the requirement that a teacher has to do six PAC modules: would it be acceptable to do six different activities, or must six modules be represented, or is it sufficient to substitute a transportation activity for some of the modules?) In this particular research, this was not much of a problem since the face-to-face interviews allowed plenty of room for clarification, but the naming of activities poses a threat to the validity of written surveys.

Paper-based forms tend not to be completed. Several volunteers noted that teachers often do not reply to written questionnaires describing PAC usage and that diligence is required on behalf of the volunteer to obtain this information. Visits to the classroom suggest that teachers may not actively seek to evade answering the questionnaire, but rather that it becomes yet one more piece of paper in an environment where there is much paperwork to be done. TRAC questionnaires are competing against other responsibilities. (On the other hand, some interviewees could obtain completed questionnaires, but this may require personal contact, incentives, or disincentives.) Questionnaires may also go to administrative personnel or a teacher no longer involved with TRAC and thus not be routed to the appropriate person.

Flexibility is required for eliciting information from the classroom. The interviewers did not find it feasible to use one set of uniform questions from the students; different approaches were required depending on the particular subject, grade level, and most importantly, individual personalities. For example, in some cases students were very creative and comfortable with a request to "design a new PAC module"; in other cases, requests for students to talk in front of the class were disastrous and required the interviewers to speak to students in small groups. The format of the teacher's lesson for that particular day also dictated how one would gather information from the students; sometimes the teacher seemed comfortable with giving the interviewers 90 minutes with a class of students, and in other instances the interviewers had to make do with a portion of a 48 minute class.

Teachers, by contrast, are very flexible when giving feedback. The teachers who were interviewed seemed capable of delivering PAC feedback under a variety of circumstances – over lunch, in a one-on-two meeting with the interviewers, during an actual lab, in preparation for another class, and in a joint meeting with others.

Some introductory information is required when requesting interviews with school personnel. Principals would initially tend to not be accepting of an interview on the grounds that they knew nothing about the PAC. It was only after explaining that they could provide important institutional information that they would agree to meet for a few minutes, whether by phone or in person. If TRAC wants to garner input from education personnel other than the teacher, it will have to make a pointed case for why those not familiar with the PAC should be present.

Self-assessment may be difficult. A surprising and positive example arose: one volunteer commented, without any teachers present, that she believed teachers' infrequent usage of the PAC was partially attributable to poor state-level training that she had provided. Yet in a later interview with a teacher who had attended this training, the teacher noted that in fact the state-level training had been excellent and had shown how to use some of the PAC materials. Without this feedback, one can envision other situations where valuable training (or some other positive action) might not take place because the offeror knew not its utility.

Innovative methods and flexible scheduling may thus be necessary for conducting future TRAC and PAC evaluations. For ongoing monitoring of day-to-day TRAC activities in the states, similar techniques to those outlined above and in the previous research approach chapter may be required.

RECOMMENDATIONS

Admittedly, many of the suggestions for the next generation PAC are interrelated: suggesting a change from a single PC-based set of activities to multiple sets of CBLs has implications for materials, curricula, and how the PAC is delivered to schools. The overwhelming recommendation from a teacher's perspective, though, is to have activities that are interactive, inexpensive, well-supported, related to a real-world application, targeted to education standards, and integrated with a curriculum that is educationally sound. Accordingly, recommendations are stratified across five categories: short-term improvements, future PAC modules, PAC curricula, the relationship of the PAC to SOLs, and how the PAC is administered.

Because of TRAC's opportunity to learn from these recommendations and the dynamic nature of the program, it is quite possible to accomplish these changes in phases rather than all at once. By periodically assessing the utility of these improvements, TRAC can spend resources in the areas that prove to be most effective.

RECOMMENDATIONS FOR SHORT-TERM IMPROVEMENTS

Several improvements may be made immediately. The eight recommendations outlined in this section exemplify the types of changes that will have to be periodically reviewed and undertaken.

1. *Acquire equipment that can be set up more easily and provide better instructions.* For example:

- The *Vernier force probe* can be calibrated rather easily by adjusting the sensitivity through turning a screw. Yet this information was not universally known. Either the vendor should be contacted or these instructions should be included in the manuals. The motion experiment is so sensitive to such factors as the ramp angle and car acceleration that it's tough to even get close to the desired results, which renders the resultant graphs meaningless.

- The *Maglev tracks* break easily, which necessitates either replacing them with an alternative design or overcoming the difficulties through making teachers' innovations available. The tracks currently do not line up well, making smooth continuous movement of cars difficult.

2. *Include some lower-cost items suggested by the interviewees*; a *printer* would allow immediate display of graphs for assignments and a *cart* would facilitate sharing among classrooms.

3. *Acquire better software.* "Better" refers to software that is user friendly, up-to-date, applicable in other situations, or more relevant to the task at hand. Specifically, this means:

- *Replace the DOS-based PC solve* with another application that runs on current operating systems, such as a spreadsheet (e.g. Microsoft Excel), a symbolic mathematical package (e.g. Maple), or a more standard computational package (e.g. Mathcad or Matlab). The main effort on TRAC's behalf would be to devise a curriculum that uses these applications. For example, one could set up a mathematical equation in a spreadsheet or a computational instrument that helps allocate snowplow usage, is used to determine roadway construction costs, reconsiders the dilemma zone associated with the yellow light problem, or even indicates how much delay will result with incremental increases in traffic volumes. By using a standard software product such as a spreadsheet, TRAC could make the case that it is helping teach students through using tools that will help them in their careers, even if that career is not transportation.

- *Use something other than the FFT graph in the speech activity (#5.2).* While the fast-Fourier transform merits discussion when studying more technical aspects of electrical communications systems, it is not as directly explainable as some of the other graphs in the PAC sound module, such as the relationship between decibel measurements and the loudness of sound. Unless students are exposed to the underlying mathematics or are given a direct, intuitive explanation in the manual of Fourier concepts, the value of the FFT graph is not apparent.[*](*54*)

- *Replace the ITS software with real software available from vendors.* The ITS module is simplistic and provides only one scenario. Alternatives, however, have not been explored. One possibility is to provide examples of software, even decision support systems, used in TMSs. Another example is to consider GIS-based products. The examples described in the first activity of the ITS module certainly merit discussion, and the curriculum can be revised such that the software suggested here is introduced as ITS components.

- *Use an alternative to Bridge Builder.* For example, *Model Smart*, a software package mentioned by several interviewees, is similar to Bridge Builder in that one can design a bridge on the PC but differs in that one can design a "software" bridge made out of locally available materials, such as balsa wood. With this product, one can design a bridge and then immediately build it.

4. *Make the software available also in a Macintosh format.* While the IBM PCs certainly dominate an enormous market share in the business world – and hence render Windows the platform for science labs donated by corporate sponsors – Apple has a large percentage of software in schools. Market share figures of 56% and 64% as of 1997 have been suggested, with Apple claiming to have the dominant position for K-12.(*55*,*56*,*57*) There is a steep learning curve associated with learning a new platform (e.g. a Mac user picking up IBM software for the first time); and thus allowing the teacher to stay with his or her operating system can make it easier to accept the PAC.

5. *Improve the manuals*. Several specific problems were identified with the manuals. One PAC strength is its ability to reach students who are visually oriented or who are hands-on learners[†]. The manuals, in that case, should be revised to capture these two segments of students in addition to those who enjoy reading:

- The draft of the manuals available to the investigators have a lot of *typographical errors* in them.

- The *file names* can be changed and lengthened; for example, the file "collisio.exp" can be renamed to "forceprobe.exp"; probably the eight-character limitation in DOS resulted in the original names.

- *Images* – both of computer screens and actual photographs – can make the manuals more appealing, a criteria teachers use when purchasing textbooks. The desire for pictures or graphics is not a recent phenomenon; a quick perusal of a 1962 United Nations handbook for teaching science shows a large number of drawings that accompany recommended experiments.(*58*)

- *More details on how to set up equipment* are necessary; for example, being told to "set up the probe about ½ a meter from the top of the track" without specifying exactly where the probe should be placed does not provide enough information. *Troubleshooting tips* are appreciated.

- *Provide a parts list* for each activity; for example, Exacto knives are needed for some of the modules. The parts list would contain (a) materials that are needed and which are included, (b) materials that are needed, which are included, but which may need to be refilled or replaced over time, such as Styrofoam, and (c) materials that are not included in the PAC.

[*] Stark et al. explain that the Fourier transform of signal x(t) is given as the integral of the signal multiplied by $e^{-j2\Pi ft}$, such that, for example, a triangle wave with $x(t) = 1 - |t|$ if $t<=1$ and 0 otherwise would have a Fourier transform equal to $\int x(t)\, e^{-j2\Pi ft}$ which turns out to be $\sin^2(f)$.
[†] This is not a panacea. While teachers indicated that most of their students love hands on activities, some students are not as comfortable with the hands-on approach. For example, some were used to having the highest test scores but were awash in the hands-on arena. Ideally TRAC would offer in each topic area something for each learner type. Realistically, though, TRAC can have the biggest impact for the auditory or hands-on learners.

- *Rewrite the titles of the modules* such that they reflect engineering or transportation concepts and are interesting; for example, use “Investigate a car crash!” and “Design a sound barrier!” rather than a title such as “velocity and acceleration” or “motion fundamentals”. If the traditional labels are still necessary, they may be used as subtitles.

- *Specify coordination issues* such as trips to the computer lab, familiarity with graphing calculators, and the involvement of teachers from other disciplines.

- *Specify how much class time the lab will take*. An hour-long procedure requires materials for multiple lab groups or that the teacher does it as a demonstration. On the other hand, a 20 minute lab in a two hour class accommodates 25 students in groups of four or five if set up as a station.

- Especially for newer teachers, *explain the logistics of how to accomplish the activity*. Specify what group size is needed, how the teacher should manage access to the machine or materials, and what can be done with students (if anything!) who are not directly involved with the experiment.

- *Classify the activity* in terms of how it is to be used: is it a demonstration, an activity that may be done at a work station, an activity that may be done in groups simultaneously, or a role play?:
  (a) *if the activity is to be used as one station in a multi-station rotation*, write a version of several other modules so that they can be used at the other stations, pairing equal length activities together.
  (b) *if the activity is to be used as a demonstration*, possibly include computer projectors as a PAC option or ways that students can use equipment that schools tend to have (e.g. a graphing calculator) so that they can participate somewhat in the activity, and
  (c) *if the entire class will do the same activity in small lab groups*, point out that multiple sets of the equipment are needed.

- Specify what *type* of activity is being done: is it an *experiment* where hypotheses are formed and tested, a *simulation*, or a *debate* where one evaluates policy options and tradeoffs?

- *Have all of the information needed to do an activity stored in one place*. For example, when trying to calibrate the force probe, two teachers working together noted that one needed to refer to two different places – the manual and an associated equipment sheet – to find the answer; other teachers noted that preparations for doing a lab required them to photocopy material from multiple places as well. (Probably this stems from a difference in perspective: a PAC designer views the entire PAC as a single unit whereas a teacher views the PAC as a collection of discrete units. This is not semantics: a PAC designer might view it as acceptable to have a single PAC with technical instructions in the manufacturer documentation and curriculum in the manual whereas teachers view that as scattered).

- Where appropriate, consider a *one-page student-based lab report form* that can be photocopied. A data table that teachers can distribute will help use class time efficiently.

- *Cover basic topics that are essential to doing the activity* such as the difference between independent and dependent variables, how to set up and solve a mathematical expression, and key definitions, such as the meaning of elastic and inelastic when describing a crash barrier. *When appropriate, provide a list of sample data or expected outcomes* for newer teachers, so they can know if they are on the right track. Ensure that the modules are self-contained such that a new teacher could understand the underlying theory without consulting reference material.

- *Add flexibility to the step-by-step instructions in the manuals*. The interview responses showed that some persons liked the sequential instructions, others needed even more detail, and still others wanted more open-ended questions. Probably the answer lies in the “graduated approach to problem solving” articulated by one of the teachers, where students of different abilities will need different amounts of guidance. It would be appropriate, therefore, to have the manuals showing step-by-step instructions under broader questions so that students have an overall understanding of what they are attempting. Ideally these instructions would be classified according to the three step learning cycle: the exploratory concept, the activity, and the application to a new situation.

6. *Show, in the manuals, that transportation is open to women and minorities*. This might be as simple as replacing the word "he" with "she" or "the fighter pilot", or it might entail including women and minorities in the photographs that would be added to the manuals. The Institute for International Research Consortium advises that textbooks "incorporate activities that specifically involve girls and introduce positive stories about women and girls and their contribution to society."(*59*)

7. *Provide videos or slide presentations that highlight engineering challenges*. Media presentations such as that offered by FHWA regarding bridge construction, directly interest students. On the other hand, students and teachers do not want to watch the video describing the PAC itself.

8. *In the short term, consider creating a revised video* for teachers or students that trains them in how to use the PAC equipment in greater detail. Other technical aspects of select PAC modules may be described in detail; this would help bridge the long gap between training and when the teacher uses the module in the classroom. In conjunction with the idea of letting users choose which modules they want to acquire rather than forcing them to purchase the entire PAC, it would be appropriate to have discrete video sections each corresponding to the appropriate activity rather than a single video that describes the entire PAC. The student video could be presented in four parts for select modules: the first part directly relates the module to real world applications, explaining why professionals perform this type of activity; the second part provides enough information to begin the module; the third part provides troubleshooting ideas after students have attempted the activity; and the final part wraps up what has been learned from the activity.

RECOMMENDATIONS FOR NEW MODULES

Several new lessons have been suggested based on volunteer, educator, and student input as shown in the interview syntheses. The **ninth** recommendation is to consider the following modules in the PAC that are *loosely* grouped in the areas of areas of construction, operations, planning, and technology. These groupings are not all-inclusive but instead are one way of categorizing and building upon the suggestions from interviewees.

Construction-Related Modules Include:

An environmental module. Specific emphases on the environment, such as air quality (e.g. exhaust emissions, air quality modeling), noise pollution (e.g. the properties of sound absorbing substances), water pollution, erosion, wetland, and botany issues, and the impacts on humans and animals of specific types of pollution such as light or airplane noise. By far, this environmental module was one of the most frequently suggested. Specific examples were given by interviewees, such as using plant life to filter out chemicals produced by road construction or the transportation of hazardous materials (which could be done in the form of a simulation). Since a major portion of civil engineering involves hydraulics and water quality, an activity, even in the form of a field trip, would be appropriate for that subject.

Physical construction of a model bridge. The students would begin to learn about how tension and stress affect structural design and how bridges degrade over time, yet this could be expanded to include relevant policy questions such as improvements to the design versus cost, what types of soil should be used, and whether the bridge should be paid for with tolls, bonds, or out of a general transportation budget. Traffic engineering aspects such as where tollbooths should be placed (to mitigate both traffic and CO_2 emissions) could be brought in as well. This hands-on module could be included with appropriate software, such as ModelSmart as is used in West Virginia.

Roadway design. The construction of intersections, interchanges, and physical roads replete with the use of tables for highway capacity computations and the attainment of safety standards are an application of mathematics that can be understood at the high school level. Specific problems of interest may be presented; for example, runaway truck ramps would be useful as these can relate physical laws to the real world.

Right-of-way acquisition. One specific concept that should immediately be included in the PAC was presented at the 3rd Annual TRAC conference: a two-dimensional roadway right of way problem, where a volunteer explained that students are given a large sheet of paper and, in groups of two, must determine *where to place the roadway* so that it connects two points and destroys as little land, wetlands, and development as possible.(60) The question of whose homes, schools, airports, and parks enters into the decision process, as well as the desire to make the roadway safe.

Surveying. Surveying skills are not only a fundamental part of civil engineering, but they use some of the geometry and trigonometry concepts taught in high school. Such a module would allow for volunteers to introduce advanced technologies, such as laser-based theodolites and GPS receivers as appropriate.

Operations Modules Include:

A crash investigation module. A lot of important geometric design principles, physics concepts, and analytical skills can be pulled into one unit: how to determine what happened at the scene of the crash. The fact that this involves law enforcement, carnage, high speeds, and detective work can be used to interest different types of students.

Highway safety may be included in different examples. One, as pointed out by a New Mexico school, pertains to drunk driving which is a serious auto safety problem in the Indian community and would be both interesting and instructive to the students. Another considered by students at a West Virginia high school would be how to analyze crash information; for example, one has data from the numerous crash investigations, how does one use this to reduce the risk of a crash?

Snow crew allocation. It is actually quite a challenging problem when figuring out how to use crews for snow removal. One has to consider the reliability of weather forecasts, the desire to take care of one's employees, the fact that one wants to use employees in the most effective manner possible, and union rules, such as the required number of hours of rest between shifts. Options include placing crew members on standby (giving them overtime pay without work), assigning them jobs to do immediately but asking them to also be ready to work later (giving them overtime pay with overtime work), or sending them home without pay (no pay but no work). The problem is that there are risks with all scenarios. Note that this has both a mathematical component and a unions/negotiations component as well. On the same topic, there are also problems with determining *what should go into deicing chemicals*, after one accounts for salt content, variations in salt types, dew point, and barometric pressure.

Traffic congestion can be included, where students examine why congestion occurs and how it is alleviated. This is a prime example of a module that on the surface would have purely a mathematical or scientific focus, where initially one uses the HCM or similar mathematical expressions to compute levels of service. Realistically, though, a number of methods are used to reduce congestion, such as signal timing improvements, electronic tolling, land use planning, and ITS, and these could be presented in a format appropriate for a debate or public speaking class. This exemplifies the ability to bring TRAC into other classes besides math and science.

Planning Modules Include:

Cost, budgeting, accounting, and financing. For example, cost calculations may be combined with the bridge software, especially in terms of how to finance the cost over the life cycle of the bridge. One could expand this focus to other transportation activities, such as gas mileage, transit activities, airport construction, or high speed rail construction. Indeed, given that cost is such a major factor in transportation decisions and that economic growth is frequently touted as a benefit of transportation infrastructure investment, a cost module should certainly be included in the PAC. Such a module may use commercially available software applications, such as spreadsheets, databases, or symbolic packages.

Roadway interfaces with other transportation modes. Maglev concepts are introduced, but in the classes observed by the investigators the focus was on designing and building an actual vehicle rather than considering how to realistically implement this mode of transportation. Aviation and rail, especially from a freight perspective, are not covered. A suggestion that arose from a New Mexico volunteer is to include s*oftware for managing a center*: such as ships at a harbor, trains on a track, and landside access to a port facility simultaneously.

Internet research. One teacher suggested that students assume the role of detective to learn about other subjects, such as how a state DOT is organized and what are its highway standards. This module would require some strong coordination with the appropriate state SOLs in English, social studies, or other subjects with a research component; this module also offers a tangible opportunity to bring TRAC into a class other than math, science, and technology.

Power brokers (a working-together module). Surprisingly, one group of students suggested a similar underlying lesson to what is being done with a Federally funded ITS "game". The game involves different players and stakeholders using ITS technologies, and players quickly learn that to get anything done one has to work together.(*61*) Without being aware of this game, students from one high school suggested a GPS based scavenger hunt, where a group of students have to find a location in a maze, but where each student only has some of the necessary information. The students have to work together to locate the hidden bounty.

Technology Modules Include:

A GIS/GPS component. While "maps" can be acquired over the Internet and will garner student attention according to teachers, the intelligence behind this software as well as the satellite technology that makes global positioning systems feasible is worth explaining. The module could also include a more historical approach covering how Christopher Columbus used triangulation to navigate his ships. The GIS component may be tied into a geography course, especially the notion of projections (e.g. Lambert Conformal Conic) and the resultant distortions. The role of the mapping component, though, should not be understated: the map or similar picture can be a "hook" that attracts students to GIS technology. These GIS/GPS ideas were suggested by both students and teachers.

Computer programming. For some classes, there is the potential for bringing in languages such as Visual Basic or Visual C++ into a transportation-related environment. Here, the emphasis would be on devising transportation lessons that use these languages. Many examples are available from the transportation planning field, such as the allocation of vehicles on roadway networks (e.g. the gravity model). In fact, at the time of the interview, a teacher indicated his students were using C++ to make improvements to the yellow light problem. On a simpler level, teaching students to manipulate existing software, such as spreadsheets, would be incorporated into several modules.

CADD and 3D modeling. Technology classes are already using computer-aided drafting and design (CADD), and 3D modeling (still frames) and 4D modeling (animation sequences) are becoming increasingly important. While these technologies are feasible only with a computer, they would be one way for TRAC to take advantage of technologies that already exist but lack a transportation component. Most importantly, this would allow TRAC to capture those persons who have an interest in computer modeling and graphics who might not view transportation as a career field suitable to their interests.

Automotive engineering. One teacher pointed out that students are very interested in how cars are engineered, and there is a lot that could be brought in to the such as the optics within the dashboard design as well as design issues concerning the suspension, the motor, and the electrical system. In particular, some of the existing items in the PAC – e.g. the motion sensor or force probe – may be used in a radically different fashion in the future PAC: as an introduction to ITS applications such as collision warning systems and automatically controlled vehicles. Sensor reliability would be part of this application; hence equipment failures would be planned for an integrated into the curricula.

When designing these modules, consider these principles as well:

10. *Use lessons that can be done by multiple students simultaneously*. One of the most common complaints was that a one-computer PAC will not suffice in the classroom: a demonstration is not as effective as a hands on experience. CBLs and site-licensed software can avoid this problem as schools increasingly have multiple CBLs per classroom.

11. *Use equipment available from the state DOT.* A recurring theme from the interviews is that this is a good idea for two reasons. *First*, the strongest asset of TRAC – the volunteer – is more comfortable with equipment she uses in her daily work. This will not eliminate all problems with familiarity, as a DOT contracting officer may not be aware of how a transit is used in practice. There is a greater probability that the officer could find a surveyor within her organization to describe the use of the transit than she could find a DOT person who can troubleshoot the motion detector. *Second*, the students tend to understand the difference between learning something they will use in the future and learning something just because it is used in the classroom. DOT equipment has the real world edge. Materials such as simulation software (e.g. CORSIM), hardware (e.g. sign materials and pavement samples), promotional videos or products from contractors (e.g. for impact attenuators), field equipment (e.g. GPS receivers, a measuring wheel, or construction tools), and materials for working with the public (e.g. a set of construction plans or presentations for a controversial project) are of use.

12. *Use locally available, inexpensive materials when possible.* Materials such as Popsicle sticks, string, and so forth can be acquired by teachers rather easily; on the other hand, getting replacement track for the Maglev cars is difficult, time consuming, and involves a good deal of red tape. Feedback from teachers can highlight what types of materials can easily be acquired.

13. *Use school-based technologies when possible.* Specifically, use items that are available in the schools, as illustrated by the results of these interviews and an assessment of some of the products available from educational suppliers. These include calculator-based labs (CBLs) or graphing calculators, site licensed-software (that can be accommodated with a computer lab), and CD-ROMs that are increasingly available. Many of the PAC's current and future scenarios, such as the town meeting, may be placed on CDs in an effort to give educators and volunteers additional ideas for how to conduct the module in the classroom.

14. *Whenever possible, design lessons that require materials which can be provided by multiple suppliers.* The literature review illustrates that if common types of equipment are employed, such as CBLs, then one has a choice of vendors from which one can acquire equipment such as probes or graphing calculators. This would be advantageous in order to take advantage of innovations in design, cost decreases, and discounts.

15. *Use lessons acquired from other sources as a starting point and then relate them to transportation*. Interviews already revealed that teachers have "favorite" hands-on activities. Examples include building a model car powered by a CO_2 cartridge, a "siege craft" for attacking a medieval castle, an apparatus for an egg drop, a balsa wood bridge, and topographic maps.[*] Yet teachers suggested other hands-on activities as well, such as placing a bar of soap outdoors and observing how much pollution is acquired by the soap. A useful niche for is to add a transportation twist to successful activities. For example,

- *Crash a model car* into different types of materials, thereby providing a lesson on impact attenuators.

- *Develop SimCity scenarios* so that students could learn actual transportation concepts such as placement of a roadway given existing infrastructure? SimCity would need to account for realistic traffic limitations; it may be possible to build this feature into the scenarios. Currently, SimCity is often used as a reward as an individual, unsupervised activity and is not used to its full potential.

- One teacher suggested giving students a prebuilt city *with a specific problem* in mind (e.g. the city has a high crime rate because the budget has no money for the police department). Specific problems and types of answers could be envisioned for SimCity with pre-built transport scenarios.

- Finally, *an interesting twist is to relate existing transportation educational materials to the appropriate school level.* A prime example is the University of Michigan's "ITS Deployment game", a board game for teaching agency representatives how to work together to implement ITS.

[*] In addition to the interviews, Western Albemarle High School provided some of these examples.

There may be opportunities for TRAC to either use this game as is or to work with its sponsors to specify how the game could be tailored to meet the needs of the high school classroom.

16. *Keep in mind the benefits of hands-on versus high-tech activities.* High-tech – especially nice graphics – can attract students and may be expected. Once the activity is underway, though, students generally like something they can *do*, on a PC or with their hands, as opposed to watching something done by other persons. Hence the more hands-on, the better!

RECOMMENDATIONS PERTAINING TO PAC CURRICULA

Curricula are as important as materials, as outlined in the next six recommendations:

17. *Periodically involve educators in curriculum design and activity selection.* Knowledge of low-cost hands-on activities may reduce PAC costs, render it more unique, and help design defensible curricula teachers need. For example, teachers desire *guidance on how to assess student achievement*, an item not in the current PAC. This guidance might be posted on TRAC's Website after an initial round of PAC activities had been distributed and teachers invited to specifically answer "how do you grade students when they perform this activity?" or "how do you assess students' readiness for an activity?"

18. *Develop PAC modules in a cross-curricular format*. For instance, the town meeting activity could satisfy communications (public speaking), English (for a written argument), sociology and psychology (impact of road building on neighborhoods), economics (finance, loss of business), biology (environmental impact), chemistry (hazardous materials in construction), and physics. In the yellow light problem, one may include a social studies component that asks "How do you decide where do you put a light in the first place?" From a safety perspective, the idea that perception time, decision time, and reaction time have to be figured into the phasing affects students, especially those that drive. One can also contrast the social aspects of signal placement with the traffic engineering warrants, but the policy debate is critical.

19. *Include activities an open-ended question and/or problem-solving*. The literature highlights the importance of a three-step learning process: an exploratory activity, a learning activity, and application of the lessons learned to a new situation. Within this process there is room for questions with more than one correct answer, especially in applying a familiar concept to a new situation. Dr. J. M. Hilton notes that a problem-solving activity has five discrete characteristics:

- *multiple steps* (e.g. painting a room requires deciding which surfaces will be painted, computing the area for walls and ceilings, and then accounting for the cost of the paint),
- *consideration of alternatives*. (e.g. various techniques to reduce congestion-how do you choose?),
- *divergent thinking* where one creatively considers multiple correct or feasible answers,
- *gathering all the facts*, especially when there are multiple disciplines involved,
- *organizational skills* such as outlining who will accomplish the different steps with an agenda.

20. *Provide a multiple tiered curriculum.* Diversity of subject area, student ability, and learning style means a one-size fits all curriculum is not feasible. A teacher might use the Maglev module, for example, in 8^{th} grade and later in 11^{th} grade: lessons can be learned in both instances, but the way in which the PAC material should be presented will vary. Furthermore, some teachers will be new to the PAC experiments or to the entire subject area. To develop a multi-level curriculum for a particular module, consider these steps:

- *Start with two tiers.* These may vary by grade level, course level (e.g. general science versus an advanced course in physics), and reading level. With experience, more tiers may be added.

- *Design modules in a continuum.* One concern of several volunteers has been that once a module is done in a year, there is no "higher level" to which students may be taken. If, however, students undertake a city planning module, there are ways to make tailor such a module to a 6th grade social studies class as well as an 11th grade history class, such that the activity is not duplicative.

- *Use the Web to update the module instructions.* Web access is limited but increasing, and teachers, at least, can usually obtain access. The Web could contain module summaries, detailed instructions, and troubleshooting tips.

- *Make module duration flexible.* Some teachers have block schedules with two-hour periods where they are desperate for activities that will keep the students entertained, while other teachers are forced to do everything – lab, lecture, and setup – in 48 minutes.

At least a few students (and perhaps teachers) have suggested that if a goal of the PAC is to encourage an interest in transportation-oriented careers, then the PAC needs to be made available before high school. Several interviewees noted that by the time a student reaches 11th grade, she or he is "locked" into a particular course of study; even if a student suddenly becomes interested, say, in bridge design and realizes calculus would be beneficial, by then it is too late to take action. These persons argue that the PAC should be geared toward the intermediate school level (e.g. 6th through 8th grade). Rather than eliminating the PAC's role in high schools, one can use multiple tiered curricula to target older and younger students. (There a couple of former students, as shown in Appendix D, who indicated that exposure to the PAC in 11th and 12th grades did influence their career choices).

21. *Carefully assess writing requirements.* Writing is a double-edged sword: students almost always disliked writing compared to other means of communication, yet teachers and principals noted the importance of being able to write well. For situations when students will not want to write, curricula that require moderate amounts of writing with substantial underlying thought may be most appropriate. For example one teacher noted that students need to know how to develop a proposal to solve a real world problem, such as designing an automobile. Students may integrate cost analysis, design requirements, data, report-writing skills, and presentation abilities as part of a PAC module on venture capitalism. The challenge for PAC module designers becomes to develop a curriculum that helps students use writing to focus their thoughts. (Students noted they mind writing less when they can express their own opinions.) This task illustrates how educators should be involved: working with designers, they may find ways for the module to encourage students' desire to write.

22. *Consider the value of pictorial and oral responses.* The student responses often included drawings to convey a point as well as speech. Students still must write well, but exercises can be complimented with options to create a diagram and/or make an oral presentation.

RECOMMENDATIONS PERTAINING TO STANDARDS OF LEARNING

Although in a state of flux, meeting national and state SOLs is an excellent selling point for TRAC. The PAC can be viewed as helping teachers accomplish their objectives rather than extra work. To integrate the PAC activities with SOLs, the following steps are suggested:

23. *<u>Relate</u> the PAC to the current state SOLs with the help of each state's DOE representative*. It is quite possible to tie PAC modules, existing and proposed, to curricula for each state as has been done in Appendix B. The level of detail required for this effort will vary. In some cases and subjects, an SOL is akin to "experimental design"; this type of situation gives great flexibility when it comes to matching the PAC to SOLs. In some states, however, detailed SOL tests are planned, where students would not receive credit for the course unless they passed the test. In such cases, one has to ensure that specific benchmarks, such as knowing force is the product of mass and acceleration, are met. The policy question arises as to whether this is the responsibility of TRAC national headquarters, the state DOT, the state DOE, or the individual volunteer and teacher. This may be addressed on a case-by-case basis; in any event, the persons who do link the SOLs should have classroom experience, be conscientious educators, and be aware of the DOE environment regarding SOLs.

24. *Update the PAC's relationship to the state SOLs with ongoing help from the state DOE representative.* This task is endemic of TRAC in that it must be done continually as implementation of the SOLs may change over the next few years. If funding becomes available from other sources for schools to meet SOLs, this could help TRAC help schools.

25. Have a *double reference of state SOLs* for the PAC: one list would be ordered by SOLs and the other list would be ordered by PAC modules.

26. *Emphasize the PAC's strengths as they apply to trends in the national standards.* The National Research Council writes "Few students understand that technology influences science" and later notes the influence of history on science. TRAC can focus on these two issues in a transportation context, beginning with some of the well-known urban planning problems and benefits that have arisen from increased mobility. As an illustration, consider the noise barrier and crash attenuator activities; both focus on properties of materials, but for different reasons. One way to incorporate history's impact on science is to show how research on materials' properties has been affected by technology; as suburbanization has increased, the need for noise barriers along formerly rural Interstate highways has grown accordingly. This may be coupled with a debate that entails both the policy role (e.g. should we influence residential growth) along with the technology role (e.g. how can materials mitigate the noise pollution that will result from traffic?)

27. *Emphasize TRAC's strengths as they apply to desired skills reflected in these Appendix D.* Teachers place less importance on rote memorization (e.g. one pointed out "do not let vocabulary get in the way"); they and their principals emphasize real problem solving. Having students use a graduated approach where they devise their own sequence of steps to obtain a solution from a set of constraints is one technique. Certainly students have to learn facts and algorithms, such as knowing the amount of strain a bridge can sustain. Yet using this to devise the best bridge design where one must consider cost, aesthetics, and public perception is more of an open-ended problem that meshes well with TRAC.

RECOMMENDATIONS FOR THE DELIVERY AND ADMINISTRATION OF THE PAC

One of TRAC's biggest strengths can be that unlike a static piece of equipment, TRAC provides a real person who can present the modules in a real-world context. Unfortunately, a volunteer is not always available, which places pressure on the PAC delivery system to keep the PAC up to date. Observations from the interviews and the literature suggest how each PAC module needs to be delivered if it is to be sustained by state DOTs or DOEs or TRAC National Headquarters.

Intuitively, think of the PAC delivery system as requiring three components: a *physical* component, a *communications* component, and an *institutional* component. In the past, TRAC has met primarily the physical component: delivery of materials to the classroom. The *communications* component between the classroom and TRAC should continue to be addressed through training but can be supplemented by the use of the Web, which has tremendous potential to keep this information current. The *institutional* support, however, has been lacking, and one way to shore this up is through a linkage with the state Department of Education.

Related recommendations are:

28. *Use the TRAC Website as a primary delivery mechanism.* While delivery of some materials may still be done by mail service, especially for those teachers without Internet access, the Web has the potential to keep this information current. Several features should be available on the TRAC Website:

- *Answers to questions students usually ask!* These include how much a transportation professional makes, what courses one should take in school, what the job is like, the extent to which math is used, and college entrance requirements. Other interests include what kinds of carnage a transportation professional gets to investigate and whether transportation is worth mentioning.

- *Updates of the link between PAC modules and standards of learning*. Relating the PAC to individual state SOLs will probably be an ongoing task that is most effectively done by a variety of people: in some states the linkage will not be done at all unless it is done by TRAC headquarters, but other states may be able to keep the linkages updated themselves.

- *Improvements to curricula provided by teachers and volunteers.* As they develop innovative ideas for using available PAC materials (such as the rewrites being done by one Colorado high school's technology lab or the linkage of crash results to the lesson on force as suggested by several New Mexico volunteers), the TRAC Website is a natural location to showcase these curricula and data.

- *Updates to software.* Not only are newer versions of the existing software packages available, but it is also becoming evident that there are cases where it becomes apparent that new packages previously unconsidered will better serve the purpose of TRAC.

- Periodic verification from volunteers as to whether *the revised modules represent transportation careers.* Improvements to the manuals may also be accomplished via the Web.

- A *visual aid library* for volunteers to give students something to relate to prior to an activity or to trigger discussion.

- *Feedback on the availability of materials.* Over time, it becomes evident which types of materials are hard to replace and which modules are worth keeping.

- *Feedback on the utility of newer modules.* An idea may sound promising in theory but prove to be difficult to implement. A prime illustration is two teachers' contradictory views regarding SimCity: one teacher who had tried to use it noted that even the pre-built scenarios take too long to use in the classroom, while other teachers who had not used SimCity suggested the idea of a pre-built scenario as a solution. The goal should be for TRAC to try a set of these ideas and over time obtain feedback so that activities that routinely fail are dropped while lessons that are usually successful, or which can succeed with innovative applications, are retained.

29. *Realize that keeping the Website updated will be a major effort.* Much of the duties for keeping TRAC in the classroom require ongoing coordination. Doing the above changes with the Website will require substantial updates for the TRAC National Headquarters Webmaster, as the information for the site would come from different sources: teachers, DOE representatives, TRAC volunteers, and suppliers of educational materials.

30. *Use volunteers, educators, or DOE personnel and a Website along with rewards to monitor the TRAC program*. The volunteers who made innovations to the PAC were able to know what types of materials are (or are not) available in the classroom because of frequent visits to the classroom. It does not appear likely that the type of information described in the interview syntheses will be garnered through a survey; indeed, the interviewers found that in the meetings in person, additional time had to be spent clarifying the problems initially described by the interviewees. The free-response answers given by teachers, volunteers, principals, and students proved invaluable; it is difficult to see how this information could have been acquired by a written survey. To lessen the burden on these live people, however, three supplemental strategies may be used to monitor the TRAC program in addition to (not in replacement of) periodic conversations with persons in the classroom:

- in the short term, have teachers update *their use of the PAC via the Web*. Teachers would need some type of reward for doing this (e.g. a free laser pointer for suggesting good improvements or teaching a certain number of modules). Good ideas from students may be included.

- in the short term, consider a *short survey* as is used by some state DOTs where teachers can give very short answers, such as a checklist of the activities within each module that have been used.

- in the medium term, consider an *awards program*, where teachers nominate volunteers or vice-versa. This could later be enhanced with trips to the national meeting for award acceptance.

- in the medium term, *monitor teacher and volunteer turnover*.

- in the long term, *monitor the progress of former TRAC students*. A few former students have been tracked, usually the "success stories", but the real litmus test of TRAC is to see how the PAC affects larger numbers of students. Since this is an arduous task, it should probably be started on a small scale, such as working with schools that keep track of former students (as is done by one private high school in New Mexico).

31. *Consider the many suggestions from teachers and facilitators emerge as a way of maintaining excellent volunteers*. While some of these suggestions will require additional funds or management support, some are feasible now:

- *Use better recruiting*. While some respondents noted that ideal characteristics included being outgoing, charismatic, young, enthusiastic, female, and alumni, successful volunteers may take on a variety of characteristics. The important aspect is to find individuals who will work to make TRAC viable in their given situation.

- *Provide additional training* and monitoring for volunteers' experiences in TRAC.

- *Institutionalize an annual meeting between a teacher and a volunteer*, as suggested by a couple of states, where teachers and volunteers assess how the PAC will fit within the required curricula.

- *Standardize newer volunteers' responsibilities*: West Virginia, for example requires new volunteers on their first visit to the school to simply observe the teacher and on their second visit the volunteers discuss careers. This gradual approach helps new volunteers become comfortable in the schools.

- *Develop a standard process for handling volunteer turnover*; pairing volunteers such that one is always up to speed while one is newer may help the program maintain its momentum.

32. *Package each module separately*. Many teachers want to be able to purchase multiple sets of certain materials so that they can use the activity as a hands-on application rather than a demonstration. Yet no teachers appeared to use all modules. Additionally, this separation of modules would make the PAC less forbidding for new users as they could focus on the portion that they need to understand immediately. Finally, PACs are often used in only one classroom in each school; in instances when the entire set of modules is purchased, this may make it easier for teachers to divide up the modules.

33. *Clarify TRAC's mission with regional centers.* Volunteers noted various TRAC purposes such as (a) to recruit engineers for the state DOT, (b) to stimulate interest in transportation from a civil engineering perspective, (c) to increase student interest in math and science, (d) to increase minority and female recruitment (either in engineering or within a state DOT), (e) to teach that transportation is an interdisciplinary field, (f) to improve local education, and (g) to portray engineering as a creative blend of humanity and science. In our opinion, one way to view TRAC is to define its mission as achieving two broad objectives and one personal objective. Broadly, TRAC seeks to

- *educate students* as to the diverse nature of transportation. This includes the additional benefits of educating the public as to what underlies transportation policy decisions and being an excellent public relations initiative.

- *recruit* potential transportation employees, whether these would be equipment operators, technicians, policy analysts, engineers, or administrators. Although civil engineering remains at the core of construction and maintenance operations, clearly there is a need for the recruiting to attract persons with diverse interests including software engineering, ITS, environmental studies, law, etc. TRAC is not limited to persons who will attend college: the key feature of a person to whom TRAC should appeal is an interest in transportation.

Yet part of TRAC's appeal is the personal commitment on behalf of the state or volunteer. This personal objective may then emphasize any combination of items (a)-(g) shown above.

34. *Formally involve some state DOEs in the distribution of PACs*. Some state DOTs are extremely active and accomplish PAC distribution satisfactorily. In other states, however, it may be suitable for TRAC National Headquarters to work directly with the DOE. At the very least, alerting DOE to the existence of the TRAC program may help those teachers who do not have access to the Web to obtain updated PAC modules.

35. *Introduce the PAC in person to the teacher*. While the Web is a great way to keep details current as well as facilitate information exchange, it cannot replace initial human contact. Face-to-face aspects of TRAC, such as the annual training and the volunteer meeting his or her specific teacher, remain essential.

EPILOGUE

There are several directions TRAC may follow with respect to the PAC and the program as a whole.

WHAT IS THE NEXT GENERATION PAC?

The abundance of educational materials suggests two broad options for further growth if TRAC wants to sustain a classroom presence. *One option* is that TRAC could compete directly with the providers of educational materials, trying to provide hands-on activities that are cheaper, more accessible, have more developed curricula, and are better supported than those available from private providers. This is not impossible; interviewees noted they like TRAC's support via volunteers and training. It certainly does seem daunting, though – at the very least, one would want to consider that some of the PAC's activities would not survive if teachers had the choice of paying for them versus paying for others.

Alternatively, the PAC could become a means to bring real-life experiences to the classroom, focusing on the strength of TRAC: its volunteers. For example, as outlined in the Maryland social studies SOL, understanding the "impact of media on public opinion" can readily be examined through newspaper coverage and public perception of a newsworthy transportation issue. The challenge is teaching the volunteer how to present this information so that it captures student interest and meets the necessary state SOL. The volunteer would want to convey the diversity of transportation careers, noting that often a single position requires a blend of technical, financial, and leadership skills: even a single task such as roadway design requires balancing capital cost, driver risk, aesthetics, property owners' rights, and politics.

One of the best ways to envision how the next generation PAC should be developed is to study a specific module that is proposed: the two-dimensional roadway layout problem presented at the 3rd Annual TRAC Conference. In this activity, students pick the location of a road that must connect two points, meet design criteria, and be acceptable to the community even though it will destroy parks, schools, homes, and businesses depending on its location. In its present form, this is a viable activity that can be used immediately.

Consider the salient features of this roadway design module: it originated based on feedback from a volunteer, it encompasses the broader skills required in transportation (civil engineering, public relations, the ability to synthesize information from multiple sources, and communications), it has a strong hands-on interactive component, and it meets trends and standards that educators find important such as problem solving and information synthesis. How could this example fit within the next generation PAC? Would it retain its present form? Would a higher-tech version be necessary? We suggest a set of sequential steps for the next generation PAC and this activity.

1. The activity may be *posted on the TRAC Website*, where TRAC National Headquarters could update the activity with increasingly better lesson plans garnered from educators or volunteers.

2. Educators may suggest a *methodology for assessing student achievement* or for presenting the information via the three-step learning cycle, which would also be posted on the Website. This would move the activity from solely stimulating student interest to a lesson plan format that is more familiar to teachers who are not familiar with the PAC.

3. Either TRAC National Headquarters, a local volunteer, or a state DOE *representative may tie the activity to SOLs* in social studies, technology, math, or science at the state level. This moves the activity from an "extra" effort to one that gives educators a non-textbook approach for teaching a lesson. Ideally, the activity could be rewritten in a *cross-curricular* format, highlighting the interdisciplinary nature of transportation and responding to some schools' interest in time-efficient activities.

4. The activity *may be packaged in a form* that teachers can immediately use. For example, the PAC "manual" whether on a Website or in a physical book would contain a large sheet of paper that can be

photocopied as part of the design problem.* Along with the drawing would be instructions for how to teach the module, what information should be conveyed to the students, and ready-to-copy handouts. Teachers who only wanted to purchase this module, and not other PAC modules, could do so.

5. The activity *may be integrated with newer technologies* as appropriate. For example, following a cue from one of the companies that supply educational materials, a CD may be produced that contains this lesson, supplementing it with debates concerning the value (or waste) of right-of-way acquisition. The compact disc would not replace the paper module but would benefit schools equipped with computer labs.

6. The activity may be written for 8^{th} and 11^{th} grades. Educator input is used here: teachers may be able to provide insight into how the questions would vary between the two levels. The notion that 8^{th} graders cannot do what 11^{th} graders can do is of course not necessarily true because of variation in background and ability, so the key question for educators would be how to rephrase the questions so that students work to the best of their ability rather than a "dumbing down" of a good module.

7. *Customization* may be added as a component on the CD. For example, we know from the interviews that it is unrealistic to expect teachers to spend hours preparing for a single lesson. Yet we also know that students tend to be interested in issues to which they can relate. It may be possible to develop a software subroutine that automatically generates the drawing based on variables supplied by the teacher. For example, one might specify the name of a familiar town, buildings and streets that are proposed for expansion or demolition, and wetlands; the program would then generate the drawing for the teacher.

Note also that these recommendations have increasing levels of difficulty; TRAC would not want to pursue option (7), for example, until good ideas from educators had been solicited in options (4) and (6).

Finally, one may consider partnerships with other institutions that would encourage the development of future modules. Ideas for modules presented below are probably beyond the scope of TRAC's immediate interest but they do present opportunities for the PAC in niche areas, probably at the state levels:

- According to teachers and students, students dislike writing. Research should be done on *using voice-based word processing software to capture student dialog*. That is, when preparing their own ideas, students would often be willing to say much more than they would write. Application of voice recognition software for this problem could be beneficial and would fit well with recommendation 21.

- *Enhance student competition via the Web*. The PAC software may be adapted in some instances to allow students to compete against students from other schools.

- *Enhance students' interactions with practitioners and researchers*. One teacher suggested a radically unique Web application compared to what has been mentioned thus far: sponsor interactions of classrooms with live chats and downloads from researchers in the field. The teacher noted that here the Web is being used to encourage, not replace, personal communication. The attraction factor for students is that they get to hear from persons who have a lot of enthusiasm for their careers and whose energy translates into a desire to learn continuously. In a broader context, this is a crucial aspect of TRAC: persons who are interested in their careers motivate students, even if not all of the technical details of those careers are conveyed.

* The design problem ideally requires a detailed drawing on a large sheet of paper, such as 24"X36". While one option would be to include full-scale copies of these drawings, an easier method of distribution for TRAC would be to maintain the drawing as multiple pieces on regular 8½"X11" paper which students would put together with tape. A variation for those with access to newer photocopy machines would be to simply have the entire drawing be enlarged by the teacher, copying from regular sized paper to the largest size paper available (e.g. from 8.5"X11" to 17"X24").

- *Point out what types of activities are suitable for a field trip rather than the PAC.* During the interviews volunteers gave good examples such as visiting a University's hydraulics lab in order to explain to students the concept of a hydraulic jump.

- *Consider instructions in other languages*. Interviewees suggested making PAC manuals available in Spanish, which would help overcome the language barrier. In fact, there may be a possibility of writing a module in Navajo, which would benefit some students on Native American Reservations, if a partnership could be established with universities doing research in this area.

HOW CAN COSTS BE ESTIMATED FOR A NEW MODULE?

A significant portion of the PAC's costs can be related to time. Designers have an initial cost (to develop a new PAC module), TRAC National Headquarters and state centers have both a capital cost (testing and deploying the new module) and a maintenance cost (updating and improving the module), teachers have capital and maintenance costs (integrating the modules into the classroom), and finally, DOE and DOT program representatives or TRAC National Headquarters must spend time relating the new module to the appropriate standards of learning. The roadway design module that has been proposed illustrates how costs for a new module may be estimated.

- *Initial design cost*. A team of educators begins with the idea of giving students the problem of determining where to place the roadway. Using three educators and one transportation professional who can work together (consisting of low-tech drawings, questions and answers to be asked of the students, and hints for how to convey the material), it is reasonable to expect that in a five day period these individuals could produce two versions of this module. At $250 per person per day, this suggests an *initial design cost* of $5,000.

- *Testing and deployment cost*. The team relays the prototype module to TRAC National Headquarters, which then spends a person-day finding two schools at which to pilot the new module. Four more person-days are spent (one day spent by each teacher to prepare the module for classroom use and another day is allowed for each teachers to write what works and does not work regarding this new module). The design team is reconvened by phone or in person to revise the module (one day per member) and TRAC now spends three more person days posting the now-tested module on its website and fielding initial questions. This suggests a testing and deployment cost of $3,000.

- *Maintenance cost*. At a very basic level, TRAC National Headquarters might simply field questions about the new module as they arise over the coming year. Yet if the module becomes popular, then TRAC might consider writing a computer program that automatically generates different versions of the module based on teacher input. Without this added technology feature, though, one might consider that TRAC National Headquarters will spend 10 person days supporting and updating the new module, yielding a maintenance cost of $2,500. Clearly this step requires a policy decision for the module: it may be the case that TRAC elects to develop the higher – technology version at once, which affects the price.

- *SOL linkage cost*. The authors' experience with reviewing SOLS in a fashion similar to Appendix B suggests a cost of approximately one person-day per subject per state for linking a specific module to a specific set of SOLs. This includes time to review the SOL document and the need to contact appropriate DOE personnel who can help interpret which SOLs are critical, as was exemplified with the West Virginia Technology SOLs in Appendix B. Relating this module to 10 states suggests a cost of approximately $2,500.

Based on these four cost components, a first guess at the development, testing, deploying, and one-year support costs for a new PAC module is approximately $13,000. These expenses would be borne by TRAC National Headquarters or the individual states. Because computing these costs is so subjective, however, these figures should be reassessed after a few new modules have been developed. For example, teachers will often design curricula for fees of $120 to $150 per day, suggesting a lower total cost overall. Yet teachers often presume that they will be finalizing these curricula while teaching the course, meaning there may be a tendency to underestimate costs for developing a finished product. As another example, one veteran TRAC engineer was able to rewrite an existing science-oriented module, making it applicable to four different subject areas, in about 30 hours, suggesting that experience on behalf of the designer can lower development costs.

Additionally, teachers' time to learn the PAC module should also be considered. As indicated in Appendix D, modules often require at least a couple of hours of individual study, in addition to annual professional development. The goal in developing new modules, however, should be to reduce this amount of teacher preparation time. One way to accomplish this goal is to shift the burden of determining how the PAC module fits into the curricula from individual teachers to state or national-level personnel, as reflected in the SOL linkage cost component.

WHAT IS THE NEXT GENERATION TRAC?

During the interviews, the necessity for TRAC to consider policy choices became apparent. Although beyond the scope of the original study, the technical suggestions made above cannot be fully evaluated without considering these programmatic suggestions.

Develop a marketing plan for TRAC. TRAC varies by state and teacher: some schools obtained the PAC themselves whereas others received it from the state DOT. Some have never seen a volunteer and some see one every other week. Some are quite familiar with the PAC's modules whereas others know very little. A marketing plan should include the key elements of the next generation PAC provided they become its guiding principles:

- The PAC is *career oriented*, focusing on transportation but extending to math, science, technology, and social issues.
- The PAC relates to both the *real world* and issues of *interest to the local community*.
- TRAC includes a *local volunteer* who can convey positive attributes of an exciting career: an interest in a job, the desire to work effectively, and a desire to learn continually.
- The PAC includes a *national network* with training and 24-hour technical assistance.
- The PAC is *cross curricular*, encouraging students to integrate technical and communications skills.
- PAC modules are specifically related to *state standards of learning*.
- Counseling is available from the state DOT or TRAC National Headquarters regarding *alternate funding sources*.
- The PAC is *flexible* in terms of grade level, complexity, subject matter, and duration. A school can acquire all or just a few modules as necessary.

Pursue alternate funding sources for TRAC: School-to-work grants from DOEs, businesses, foundations such as New Mexico's Alliance for Transportation Research, local chapters of professional organizations, alumni contributions, and area employers have been suggested or pursued in the various states. TRAC National Headquarters may counsel states in terms of recruiting outside funding. For example, partnerships have been shown to be effective, where donations from teachers or government are matched by the private sector.

Consider a partnership arrangement with nationally based or state-based organizations that focus on educational outreach. There exist a number of organizations at the national level, such as the American Association for the Advancement of Science, and at the state level, such as the Texas Alliance for Minorities in Education, which have an interest in specific aspects of education and mentoring. It may be a productive arrangement for TRAC to make itself known to these organizations, even if the initial setup is simply that these organizations alert their members to

TRAC's existence. The University of Michigan's ITS game alluded to previously (a board game used by agencies to teach their representatives the value of working together to deploy ITS projects) is another type of example that initially appears that it could enhance the TRAC program.

Have TRAC National Headquarters work directly with DOE rather than using the DOT as an intermediary. In particular, the Colorado volunteers noted that this is a more sustainable management model, allowing the DOT to serve as a speaker's bureau but removing the DOT from the logistics of maintaining a PAC inventory, as also noted by West Virginia's Department of Highways.

Invest more in teachers and volunteers. While financial resources are always a desired outcome, there are some ways to use them effectively, including compensation for teachers' training days, overtime for teachers or volunteers, travel scholarships, paying veteran teachers as trainers as an incentive to stay active, and a small stipend for TRAC supplies. To leverage these investments, schedule training when teachers can attend; this is often close to the end or beginning of the school year, but the state DOE can provide input for the specific state and situation.

Garner support for TRAC at the higher management levels in DOT and DOE. Funding and organizational support alone do not make a successful program, but they can help greatly if the other components of a good program are in place. Once TRAC pursues improvements to the PAC, this last recommendation is worth implementing if TRAC is to be a sustainable long-term program. The more active states seem to have a champion at the highest levels. In cases where this support is lacking, a teacher and a volunteer can successfully make TRAC work for a specific school, but TRAC will not tend to spread to other schools or teachers. It is in these cases where TRAC Headquarters can play an active role in establishing the champion within the state DOT and DOE.

APPENDIX A: INTERVIEW SCHEDULE

The text below shows the questions that were targeted to teachers, volunteers, students, and principals. Not all of these questions were asked of all interviewees: time was limited and not all questions were applicable in all instances. Indeed, it would be intimidating to be confronted with a laundry list of questions!

Instead, the purpose of the questions shown below was to give the interviewers an understanding of what path to take given a response to a certain type of question. In fact, asking two questions at once may be confusing to the interviewee; hence the list of questions serves to help the interviewers make the most of the limited amount of time available to converse with teachers, students, principals, and volunteers.

Questions that became particularly relevant are shaded; those that were proven unnecessary have a line through them.

QUESTIONS FOR TEACHERS

The teacher questions are stratified into seven categories: an introduction, background information, questions about the specific PAC modules, information about non-PAC activities that have worked well or poorly in the past, visions of the future PAC, coordination with other PAC support groups such as the state DOT or DOE, and ways to reach present and former PAC students.

Introduction to the Audience

Five items were accomplished during the first few minutes of the interview: *first*, introduce the investigators, *second* state the purpose of the interviews, *third* emphasize that the interview evaluates the TRAC PAC rather than teachers, students, a school, or a state, *fourth* point out that the results of the interview will not be attributed to the interviewee, and *fifth* explain that this interview is not part of the annual survey of all TRAC schools that was being conducted in October 1998. The following text serves as a model.

> "We represent the Virginia Transportation Research Council, and we are evaluating the PAC activities as part of a national research effort. We do not represent the Virginia TRAC program nor the national TRAC headquarters. Also, we are not evaluating TRAC teachers, TRAC students, or the TRAC program. Instead our goal is to develop a vision of what the next generation PAC should accomplish."

Then, sometime before the conclusion of the interview, text similar to the following was stated:

> "We will synthesize our notes and mail a typed copy to you in case you would like to make modifications. Since the emphasis is on representing your views, you are welcome to add information that did not come up in the interview as well. Also, we have additional copies of the introductory letter and abridged proposal in case documentation is needed by your school."

Background Information

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, as it matters whether the teacher uses the PAC quite frequently or seldom and how experienced with it he or she is. Questions include the following, noting that wording may be added to the first question in order to make the interviewee comfortable with the interview process.

How often during the school year do you use the TRAC PAC?
When was your school's last TRAC module taught?
Have you used any PAC lesson plans, modules, or equipment that were updated within the past year?
Have you had a chance to use more than one module in the past year?

For the PAC, how much support do you get from
-- a TRAC Regional Center? -- state Department of Education? -- principal? -- TRAC volunteer?

Some schools have received updated modules and training; some have not.
Have you had an opportunity to receive any of these updated modules or training?

Specific TRAC modules that you have used

The purpose of these questions is to discern some facts about the current modules' strengths and weaknesses, as well as to know which modules simply have not been used. The questions may be used with Table 3.

(A) has the module has been implemented in the *past*
(B) is the module "currently" in use or planned for *future* use
(C) what is the key *benefit* of the module? (acquire, experiment, entertain, stimulate)?
(D) how much *class time* is required by the module (or if only a portion is used)
(E) how easy is *preparation*, including time and acquisition of supplemental materials
(F) how feasible is *implementation*, including the impacts of group size
(G) what is the *novelty* of the software or hardware encompassed by the module
(H) what is the utility of the curriculum or student *guides*
(I) are there *other methods* that may be used for achieving the goals of the module
(J) How well or poorly does this tie into your state's *standards of learning*?

Table 3: PAC Module Information the Investigators Had Originally Intended to Obtain

Module	Year Used A	future use B	Benefits C	Class time D	Ease of preparation E	Implement F	Novelty G	Guides H	Other methods I	SOL J
Introduction to transportation & engineering	1.									
Motion fundamentals	2.									
Math modeling	3.									
SimCity™	4.									
Sound&Noise Abatement	5.									
Magnetic Levitation	6.									
Social Studies	7.									
Other modules developed by the teacher	8.									

Do other teachers use the modules? What do they think?

Note: while the above questions served as a useful "checklist" to make sure the interviewers did not forget questions, rarely did teachers have specific information for most modules. Instead, teachers could usually recall which modules did or did not work and why, or they could offer reasons for using or discarding certain activities. Teachers did not usually, for example, recall the amount of preparation time for SimCity: instead they could indicate how they successfully used it in their classroom or why having just one PC was a severe limitation when it came to using SimCity.

Other instructional aids besides the PAC that you have used

The TRAC PAC is an instructional aid, and teachers have been using tools in the classroom since time immemorial in order to capture students' interest, expand their horizons within a topic area, encourage independent research on *behalf of the student, teach lessons that cannot be taught in lecture mode, or entertain the class. Successes and failures from these other types of aids may illustrate what the PAC should try to accomplish.*

Think of your **best** instructional aids; the ones that you use over and over again, and not necessarily part of the PAC. They may include computer simulations, role playing, games, demonstrations, or experiments. What makes you use these aids over and over again?
[Characteristics might address ease of use (teacher focus), novelty (student focus), interaction, or the ability to teach a fundamental concept not otherwise learnable (curriculum focus)].

How did these aids fit within your *program of studies* or *standards of learning*? [Give an example.]

Similarly, what were the characteristics of your **worst** instructional aids? [Give an example.]

If it is hard to keep on track at this point, then use the shaded table to elicit information about specific examples.

[If the teacher keeps giving good examples but can't think of any bad examples, then ask the following question: "Suppose I (the interviewer) was going to teach your class, and I was going to do activity X [an activity that the teacher indicates always works well.] How could I screw it up? In other words, how could I turn this useful activity into a worthless one?"

Relationship between Standards of Learning (SOLs) and activities such as TRAC

Ask the first question followed by either the second or the third. The sixth question is a backup in case the fourth and fifth questions fail.

How do you go from a state SOL or Program of Studies (POS) to what you would teach in the classroom?

> How do you see TRAC modules fitting into this scenario? **or**
> How well do the items in the TRAC/PAC mesh with your program of studies (what you must teach?)

Are there other transportation topics that could be a better fit with your program of studies?
Are there better experiments or lesson plans (than the current PAC modules) that should be implemented?
(*if necessary*) Who interprets a state's Standards of Learning or Program of Studies?

Some states used the phrase "standards of learning" but others used terms such as "content standards" or "tests". It was sometimes preferable to thus use the terminology more familiar to that particular school system.

What should future PAC modules accomplish?

These questions look beyond the current PAC to what the next generation of PACs might accomplish. It is critical that teachers not be restricted to the current PAC subject areas or current PAC format but instead be encouraged to give their view of what an ideal instructional aid might do.

Which *instructional setting* would you prefer
- -- A demonstration conducted before the class or an experiment with lab groups?
- -- If lab groups, what are the ideal and maximum lab group sizes?

Can you comment on the importance of *sophistication of equipment* versus *interactive labs*?
The PAC interfaces with an IBM computer. Are there other *standards* that should be considered?
- -- MAC platforms? -- graphing calculators? --Web functions? --

What *incentives* are there to try a new instructional aid?
- -- student interest? -- encouragement from the school administration?

Is the program *real-world* enough? (Should, say, the motion sensor be replaced with a transit?)

How can we reach former TRAC students?

~~How can we reach former TRAC students?~~

~~-- Did you ever get feedback when a particular module made a difference to a particular student?~~

~~Can you recommend other TRAC students we might interview in this school?~~

~~-- Is it possible to interview them together not too long after the TRAC session?~~

~~-- Is there a club of [science, math, social studies, etc.] students who would be willing to meet with us for~~

~~a few minutes after school?~~

Although many teachers were asked these questions, they were finally deleted as it became clear that contacting former PAC students is not very feasible. While the interviewers did periodically bring this up during the teacher interviews, it seemed more fruitful to ask this question at the state DOT level rather than at the educator level.

Backup Teacher Questions

Each interviewee responds differently to the various questions. The questions above target the PAC in one manner; but some teachers may respond better to more open-ended questions. Should the above questions fail in a particular area, then the questions shown below may be used to supplement the regular interview. Otherwise, the three target areas (student interest, duplication of efforts, and delivery mechanisms) are covered in the preceding questions.

Student Interest
How well do the various modules capture the students?
Are there different technologies (e.g. has the computer lost its pizzazz)?

Duplication of efforts
Could these lessons be accomplished with other types of materials?
Which is more difficult: lesson planning or acquiring the materials themselves?

Delivery Mechanisms
Ideally, how many students can work together within a module?
How are you updated about changes in other lesson plans? (should TRAC be following this?)
What are the mechanics for fitting the TRAC PAC modules into a curriculum?

In practice, these questions were asked when the interview “jumped around” quite a bit; they helped to ensure that the investigators had not omitted any relevant queries.

QUESTIONS FOR STUDENTS

The critical piece of data from the student interviews concerns <u>interest</u>: how stimulated are the students after being exposed to the curriculum contained within the TRAC PAC? The format for asking these questions varied as described in the methodology from discussions with the entire class to focus groups of a few students to individual student responses.

Think about the different demonstrations or activities you have done in you class that were entertaining and which made the material make sense.

Give some examples.
What was it about these demonstrations or activities that you liked the best?
Have you done those types of demonstrations or activities in other classes or outside of school?

Similarly, think about the worst demonstrations or activities you’ve had.

Give some examples.
What was it about these demonstrations or activities that made them a dismal failure?
Do you see this type of mistake repeated in other classes?

The purpose of this last question is to again learn from students (rather than teachers) what other types of instructional aids (besides the PAC) have been used and what made these aids successful or useless.
We've asked you about PAC activities, but what has been the best or worst non-PAC activity you've done?

Note also that experience shows it is critical to underscore for the students why they should even be concerned with transportation at the high school level. Possible arguments include noting that transportation takes up a significant percentage of GDP, that transportation expertise is increasingly in demand, and that math and science in general – not just transportation – can lead to good careers. A significant amount of time – e.g. about 25 minutes – needs to be allotted to making this case before one can begin to ask students for information.

Another tack for garnering information is to show students the current PAC activities and then ask them what goes into transportation issues they have seen in the papers or heard about. When students notice a disconnect –e.g. motion detectors cover physics quite well but do not explain key elements of geometric design or policy issues affecting highway standards or right-of-way acquisition – then students can be asked to design labs that will fill the gap. An added incentive is to have the students focus on labs not just for them but for younger students; the 11th graders in one class, for example, expressed disinterest in writing up "what you should learn" until we asked them to think about the typical 8th grader that needs baby questions.

QUESTIONS FOR VOLUNTEERS

The interviews with volunteers focus on two areas: (1) whether there are civil engineering/transportation components not covered by the modules and (2) identifying the salient features of the modules that teachers find useful. In some cases, volunteers were present with teachers; otherwise they were interviewed separately.

What is your role in facilitation?
Related to that question, who is responsible [in this state or in this school] for teaching the PAC modules: the teacher or the volunteer?

Are there civil engineering or transportation components that are *left out of the modules*?
- -- Are there lessons that would be interesting to include that are left out?
- -- Is there equipment or visual aids from the workplace that students should be shown?

When specifically are the PAC modules used?
- --What specific courses (e.g. physics, earth science, etc)?
- --What difficulty levels (honors, college prep, low achievers, etc)?
- --What grade levels (8th, 9th, etc)?
- --What are the school demographics (rural/urban, income level, % minority)?

What are the characteristics of the modules that teachers tend to *use*?
- -- Which modules are covered?
- -- How interesting are these modules for the students?
- -- Which technologies are novel?
- -- Which modules are easiest to convey to the teachers?

On a similar tack, what are the features of the modules that *are not used*?

What is the goal of TRAC in your state? In short, what is TRAC trying to accomplish?

What measurable benefits do you obtain from TRAC participation?

Do you know any *former TRAC students* that would be worth contacting?

Note: One state indicated a strong relationship with its Department of Education (DOE). For this state, a DOE representative was contacted and asked about the PAC as well as the relevance of standards of learning (SOLs). As this person focused on technology courses, the questions are geared toward that subject area. The questions for that single interview are given with the responses in Appendix D.

QUESTIONS FOR PRINCIPALS

Principals or other school administrators may play a pivotal role in a school's implementation of any new type of program, including TRAC. The purpose of these questions is to identify what features of an instructional aid will encourage support from the school's management. In case the principal does not know about PAC, the questions focus on asking the principal to identify characteristics of an instructional aid that increase the likelihood of the aid being embraced by the school's administration.

[This question is necessary, especially if principals indicate they know nothing about the PAC and hence wonder why they should even be interviewed.] As a principal, you must be bombarded daily with all sorts of educational aids or activities where the vendor promises the activity will solve all of your problems! How do you choose which ones your school should consider? In other words, what are you looking for when someone comes to your school with some type of activity that they want your school to use?

What types of skills or knowledge would cause an instructional aid to be embraced by your school?
Examples include

- -- teamwork/working in groups
- -- learning about careers [that's a TRACPAC focus – careers in transportation]
- -- enhanced decisionmaking skills (e.g. how to present tradeoffs)
- -- specific knowledge particular to a subject area (such as understanding Newton's law of motion)

An alternative way to look at this question is to ask which national standards in science, mathematics, and technology are most necessary for incorporation within an instructional aid. **In other words, what could a new instructional aid help schools accomplish that they are not doing already?**

What institutional obstructions are there to using an activity such as TRAC?

How does cost fit within your decisionmaking process?

Only if there is time permitting, then we would like to ask about the environment in which a new instructional aid may be introduced:

- -- How are instructional aids shared? (e.g. what happens when you have only one PAC?)
- -- What type of internet access does your school have? (e.g. every classroom, every student, a computer l lab, direct line versus modem)?
- -- Is there a LAN linking the computers in your school? Linking schools in your school district?

APPENDIX B: STANDARDS OF LEARNING

This discussion identifies similarities and differences among state standards of learning (SOLs) as written and interprets the significance of national standards as they relate to trends in education. It is readily acknowledged, however, that this would be a precursor to the next step: a full-blown study of how SOLs are interpreted and implemented by teachers and how often state DOEs update or revise the standards. Mathematics and science SOLs are discussed first at the state *level*, followed by examination of national science standards as well as standards from other disciplines.

RELATING STATE MATH STANDARDS TO A PAC SURVEYING/ROADWAY DESIGN MODULE

SOLs vary from state to state, in terms of the actual wording of the SOLs, their title, their role in curriculum development, their distribution by grade, and how they related to specific disciplines such as English, mathematics, or technology. The SOLs from the five states where interviews were conducted (Colorado, Maryland, New Mexico, Virginia, and West Virginia) were collected in the mathematics field. Similarities and differences between the SOLs were assessed. Colorado, New Mexico, and West Virginia SOLs were obtained directly from Websites maintained by the respective state Departments of Education.[*,†] Virginia's SOLs and Maryland's SOLs were obtained from representatives of those respective state DOEs, respectively. Maryland's SOLs are in draft form; while they are expected to be implemented, changes may be made in the interim.

A PAC "Test Module"

In order to give some focus to the consideration of SOLs, a test case PAC module was envisioned. One of the topics that at least one interviewee had mentioned ought to be included in the PAC is that of surveying. The value of this surveying module is also apparent in the suggestions of many interviewees who noted the importance of design. In this instance, suppose a module is added that represents surveying as applied to the common problem of geometric design for a two-lane road. In computing the degree of curvature, the length of the curve, and the point of tangency, and the other variables that will affect where the construction stakes should be placed, the designer relies heavily on trigonometric principles. These range from very simple "tricks" (e.g. recalling properties of similar triangles or the fact that there are 180 degrees in a triangle) to more detailed knowledge of sines and chords.

The question then becomes "how would one relate this surveying module to the SOLs for the various states?" The immediate task was to discern how each state's mathematics SOLs could relate to this proposed PAC module on surveying. This was done by assessing how the types of knowledge or skills for such a module are reflected in either general principles or specific benchmarks contained within the state SOLs.

Terminology varies by state, which may lead to confusion when making comparisons: one state's "benchmark" is another state's "curriculum." Rather than using each state's individual terminology here, the term *benchmark* is used to reflect the greatest level of specificity for a standard and the term *goal* is used to reflect the most general level.

"Colorado Model Content Standards for Mathematics"

[*] Two resources that accelerate the search for these SOLS are located, as of December 17, 1998, at http://www.putwest.boces.org/Standards.html#Section3 and at http://www.prgaustin.com/resource/currframe.html. The links from these sites did not always reflect the state DOE, however, hence each link needs to be verified.
[†] On New Mexico's DOE Website, there is a link entitled "Content Standards with Benchmarks"; DOE further writes that this is a "collaboration between the Center for Education and the Study of Diverse Populations at New Mexico Highlands University and the New Mexico State Department of Education, this site is independently hosted."†That Website provided New Mexico's SOLs.

The Colorado SOLs for mathematics outline six broad based *goals* that cover all aspects of mathematics for all secondary school grade levels.(62) Each goal starts out with a general title sentence; for example, one standard reads as shown in sentence (*a*) below. (Letters are not used in the SOLs but have been added here for clarity).

(*a*) "students use geometric concepts, properties, and relationships in problem-solving situations and communicate the reasoning used in solving these problems."

Then, for each goal, approximately four or five tasks are given that students would do to meet the standard. These tasks are less general than the goal but are still quite flexible. In the case of the goal shown in (*a*), for example, five *tasks* are shown; two of which are

(*b*) "recognize, draw, describe, and analyze geometric shapes in one, two, and three dimensions", and

(*c*) "solve problems and model real-world situations using geometric concepts."

Then, specific *benchmarks* are given by grade block (K-4, 5-8, and 9-12). Using goal (*a*) again as an example, four specific benchmarks are given for grades 9-12; two of these are:

(*d*) "deriving and using methods to measure perimeter, area, and volume of regular and irregular geometric figures."
(*e*) "using trigonometric ratios in problem-solving situations (for example, finding the height of a building from a given point, if the distance to the building and the angle of elevation are known)."

One can of course quickly discern a trend from more general to the specific as one reads from (*a*) to (*e*). One observes that it would be easier for a PAC module designer to tie a PAC module to a standard at a very general level such as (*a*). The question, though, is what would be more beneficial to teachers?

The PAC module designer could very easily relate the module to the standard shown in goal (*a*); in fact, there are a number of different topics that could be fit within goal (*a*). At a level of slightly greater specificity, one could definitely agree that the PAC module fits within task (*c*) as well: using trigonometry to determine how to lay out a roadway is an application of geometric principles to a real-world problem. Yet it is the level of greatest detail – benchmarks (*d*) and (*e*) – where there is almost direct correspondence between the module and the standard. In this case, the geometric design module would match well with benchmark (*e*).

On the other hand, the designer could argue that this module would be encompassed by some of the other goals as well, such as one which reads

(*f*) "students use a variety of tools and techniques to measure, apply the results in problem-solving situations, and communicate the reasoning used in solving these problems."

Underneath this goal, it is stated that students will do several tasks, then, for grades 9-12, four benchmarks are suggested, two of which are shown below:

(*h*) "measuring quantities indirectly using techniques of algebra, geometry, or trigonometry"

(*i*) "demonstrating the meanings of area under a curve and length of an arc"

One can quickly see that the PAC module on geometric design could be cited as meeting benchmarks (*h*) and (*i*): one must measure the length of the curve indirectly using trigonometric principles, and one would most likely be computing the length of the arc at some point during the calculations.

Finally, given the standards as written one can quickly envision how a module might be modified slightly to meet an additional standard. In the geometric design example, significant digits can become quite important, especially if the units are in kilometers such that a thousandth of a point represents a meter. By incorporating the practice of having the precision of the total computation be no greater than the tolerance of the least precise entity, one can more strongly convey what goes on in geometric design as well as meeting benchmark (*j*) under goal (*f*), which reads:

(j) "determining the degree of accuracy of a measurement (for example, by understanding and using significant digits)."

West Virginia "Adolescent Mathematics Education"

The West Virginia Department of Education maintains a Website entitled "West Virginia Instructional Goals and Objectives" where *Adolescent Mathematics Education* may be obtained.(63) This document reflects mathematics SOLs for grades 9-12, and benchmarks are grouped by course such as geometry, algebra, probability and statistics, or discrete mathematics rather than by grade level. Unlike Colorado's SOLs, there is just one level of specificity rather than three different levels. For example there are 24 and 21 benchmarks for the geometry and trigonometry courses, respectively.

Still, a quick review shows similarities among the standards in some of the West Virginia courses with those standards from other states. West Virginia's DOE writes that "Emphasis should be placed on applications to the work place and every day life.."(64) From the geometry and trigonometry courses, as an illustration, one can see a correspondence with the standards from Colorado mentioned previously, as shown in the four benchmarks below:

(*k*) "G.16: develop and apply formulas for area, perimeter, surface area, and volume and apply them in the modeling of practical problems."

(*l*) "G.12: apply the Pythagorean Theorem and its converse in solving practical problems and in deriving the special right triangle relationship."

(*m*) "T.11: solve practical problems involving triangles using the trigonometric functions, the Pythagorean Theorem, the Law of Sines, and the Law of Cosines."

(*n*) "T.19: use a scientific calculator to solve practical problems involving triangles…"

In these cases, one can see that West Virginia's geometry benchmark shown in (*m*) parallels nicely with the Colorado benchmark shown in (*d*). Likewise, the benchmarks shown in (*l*), (*m*), and (*n*) can be meshed with the Colorado benchmarks shown in (*h*) and (*i*); in fact, the West Virginia benchmark (*n*) – using a scientific calculator – can be tied to the Colorado benchmark (*j*), where students need to understand the meaning of significant digits. In this case, then, one could relate the PAC module on surveying to the SOLs shown above very easily.

"Mathematics Standards of Learning for Virginia Public Schools"

Virginia's mathematics SOLs are similar in structure to those of West Virginia: for grades 9 – 12, SOLs are grouped by course.(65) In the cases of geometry and trigonometry, Virginia gives 15 and 9 specific benchmarks, respectively, that will be covered. Considering the PAC surveying module, one can see relationships with certain SOLs shown therein in both of these courses. For example, consider benchmarks (*o*) and (*p*) shown below:

(*o*) "G.7: The student will solve practical problems involving right triangles by using the Pythagorean Theorem and its converse, properties of special right triangles, and right triangle trigonometry. Calculators will be used to solve problems and find decimal approximations for the solutions."

(*p*) "T.9: The student will identify, create, and solve practical problems involving triangles and vectors. Techniques will include using the trigonometric functions, the Pythagorean Theorem, the Law of Sines, and the Law of Cosines."

Clearly one can fit the necessary computations for the surveying module within (*o*) and (*p*). It is interesting to note that benchmark (*o*) covers two separate West Virginia benchmarks (*l*) and (*n*): among the three states, there does seem to be correlation across state SOLs but differences in organization.

"New Mexico Content Standards and Benchmarks"

The New Mexico mathematics SOLs are similar to those of Colorado in that they present approximately a dozen goals in a very general format, with various benchmarks stratified by grade block (K-4, 5-8, and 9-12) that illustrate achievement of a more general goal.(*66*) The goal cover ideals also outlined in the Colorado SOLs – use mathematics for problem solving, communicate mathematically, understand probability and statistics, and so forth. Each goal (e.g.. "students will understand and use mathematical connections") is explained by a half dozen more specific benchmarks pertaining to each grade block. Under that goal, for example, the 9-12 grade block includes benchmarks such as "assess the relationship among mathematical topics" and "evaluate mathematical solutions for problems in daily life and in the greater society."

What is a bit different is the way in which progression among the grade blocks is presented. The Colorado benchmarks as stated previously, do give very specific examples of content that must be achieved within each general goal, such as understanding the notions of absolute value and scientific notation. While the New Mexico benchmarks do this to some extent, there is an emphasis on changes that occur at each grade block within the benchmarks. For example, the first goal, "Students will understand and use Mathematics in Problem Solving", shows several benchmarks for each grade block. For the K-4, 5-8, and 9-12 grade blocks, the first benchmark under this standard is, respectively, (the underlining has been added)

(*q*) "use problem-solving approaches to investigate and understand mathematical content"

(*r*) "differentiate among problem-solving approaches to investigate and understand mathematical content"

(*s*) "analyze problem solving approaches to investigate and understand mathematical content"

It is the first few words in each sentence that differentiate this benchmark from what kindergartners to high school seniors are required to accomplish. Another example, again with the same first goal, is the second benchmark: at the K-4 grade block, this reads

(*t*) "formulate problems from students' mathematical situations"

At the 5-8 grade block, "students" is replaced with "community"; at the 9-12 grade block, this is replaced with the word "global." Other examples of this progression persist throughout the document. The document is also further evidence that organization of SOLs does vary from state to state. Yet there are clearly overlaps in the benchmarks: recalling Colorado's benchmark shown in (*d*) that pertains to perimeter and area, one can see a parallel with one of the New Mexico grades 5-8 benchmarks shown under the measurement goal:

(*u*) "define the characteristics of perimeter, area, volume, angle measure, capacity, weight, and mass"

Returning to the idea of a PAC surveying module, there are several SOLs that may be addressed. For example, the seventh goal "computation and estimation" has three benchmarks at the 9-12 grade block; the first being "develop, analyze, and explain methods for solving a variety of problem situations." The real-world problem of geometric design can be tailored to meet this benchmark, especially with different algorithms that may be appropriate for determining where the road should be placed.

The last benchmark shown within the 9-12 grade block for the measurement goal and the fourth benchmark within the same grade block for the geometric concepts goal read, respectively,

(*v*) "identify and use the appropriate units and tools of measurement to the degree of accuracy required in particular problems."

(*w*) “represent problem situations with geometric models and apply properties of figures.”

As is the case with SOLs from other states, the New Mexico benchmarks (*v*) and (*w*) definitely may relate to module on surveying: (*v*) covers the need for the location of the roadway to be computed accurately (but also addresses the problem of the least precise computation being the precision of the overall computation) and (*w*), in a more general sense, covers the goal of relating geometrical relationships to a real-world problem. As implied earlier, the trigonometry benchmark would also be covered by this module on surveying, although one would look not under geometry but rather under the goal on “algebraic concepts.”

“Maryland Mathematics Content Standards”

Maryland’s mathematics SOLs consist of ten discrete goals: six topical goals (e.g. geometry, probability, measurement) and four process goals: problem solving, communication, reasoning, and connections.(*67*) The goals are not specific to each class but instead are listed for all math classes; specific benchmarks are given for each goal at the end of grades 3, 5, 8, and 12. Within the geometry and measurement goals, respectively, two specific benchmarks to be accomplished by the end of grade 12 are applicable to the surveying module:

> “2.12.2: apply right triangle trigonometry to solve problems”, and
> “3.12.4: use various methods of indirect measure including trigonometric rations, scale drawings, models, and mathematical formulas to solve problems in real-world contexts.”

Of particular interest is the way in which the PAC surveying module could be tied to both the process skills and the attitudes of teachers who were interviewed. For example, recall that some teachers emphasized two key features they wanted in an “ideal” educational activity: first, showing that there can be more than one correct answer, and second, reflecting that the subject at hand is applicable beyond the classroom. Maryland’s “process of problem solving” goal and its “process of connections” goal show, respectively, two benchmarks that are relevant:

> “demonstrate that multiple methods to arrive at a new solution may exist”, and
> “use mathematical thinking and strategies to solve problems that arise in other disciplines.”

Certainly there may well be multiple methods to accomplish the design of the roadway in the PAC surveying module, and it can be impressed upon students that these skills they are learning in high school can be used to earn a salary as a design engineer.

Similarities Among the Mathematics SOLs

Although there are differences in the way in which they are organized, there are at least three similarities among the mathematics SOLs as suggested from either the previous discussion or further review of the documents:

- *Content required to achieve these SOLs appears similar*, so long as one considers both the actual curriculum standards and the prefacing information. For example, while the West Virginia enumerated standards for geometry tend to list specific types of knowledge that must be acquired (e.g. properties of quadrilaterals) the introductory information emphasizes real world applications.

- The SOLS express a desire for students to use *mathematics for solving real world problems including those that arise in other disciplines.* In fact, one could argue that problem solving is a predominant theme in the SOLs; tellingly, it is the first sentence under the narrative for Colorado’s goals. New Mexico notes further that students should “apply measurement as a tool in other disciplines and in everyday problem situations.”

- Teachers appear to have *flexibility in how the material is taught*; while at least one state did go so far as to provide sample lessons, none require teachers to follow a specific lesson plan to achieve an SOL. That is, there is nothing in the documents that indicates teachers could not use a PAC module to help students attain the necessary benchmarks.

- *Technology is encouraged.* All five states encourage some use of computers, calculators, or software in either a specific SOL or in a general preamble to all the SOLs. For example, Maryland's SOLs explicitly state that "Technology is embedded within each of the mathematical standards…" whereas Virginia's prefacing information for its geometry course indicates that "Any technology that will enhance student learning should be used."

Dissimilarities Among the Mathematics SOLs

There are at least three differences in the SOLs assessed, however:

- The *level of specificity* varies: in the Virginia and West Virginia there is one level of specificity: roughly one or two dozen content-based or skill-based benchmarks are given for each course. The New Mexico and Maryland standards have two levels of specificity, beginning with a half dozen to a dozen general goals applicable at all grade levels and then giving benchmarks at specific grade blocks. Colorado has three levels of specificity – general goals, tasks under the goals, and then benchmarks for each goal and grade block.

- The *organization* of the material varies: after the 8th grade, Virginia and West Virginia are organized by course, Colorado and New Mexico are organized by three grade blocks (K-4, 5-8, and 9-12), and Maryland is organized by four grade blocks (K-3, 4-5, 6-8, and 9-12).

- No *explicit* mention of the role of the *National Council of Teachers of Mathematics* is made for Virginia and West Virginia's SOLs; by contrast, the New Mexico, Colorado, and Maryland standards make explicit reference to the NCTM's impact. It is quite possible, though, that the NCTM was a strong influence in all cases even if it is not cited directly.

ORGANIZATION OF SCIENCE STANDARDS FROM FIVE STATES

Standards of learning were also considered in the science field for the same five states: Colorado, Maryland, New Mexico, Virginia, and West Virginia. The amount of organization, level of detail, and cited sources vary, yet there are certainly similarities in terms of content. Note also that there are parallels within each state's math and science SOLs; for example, Colorado has three levels of specificity in its science standards just like it has three such levels in its math standards. Just as Virginia's high school math standards are done by course, so are its science standards. One can also tie a specific PAC module to each of the science SOLs as was done for math SOLs; however, the main challenge to understanding the science standards appears to be understanding their organization. Hence in the interest of brevity, organization is the focus of this section.

While there are many ways to describe the information in the science SOLs, one can consider two broad interrelated categories: the first focuses on *applying scientific techniques* (e.g. constructing a hypothesis) and the second reflects *information* (e.g. the meaning of kingdom, phylum, and species). This does not mean that these two categories are mutually exclusive; one might learn the different parts of a cell as well as study how scientists investigate cell theory.

This distinction between scientific techniques and information is useful, however, because it gives different avenues for relating the PAC to the standards. In some instances it may be appropriate to relate a PAC module to a scientific technique, such as investigating the cause of a crash when the police officer arrives at the scene after the driver has left. In other instances it may be more productive to relate the PAC modules to specific content students must know, such as Newton's Laws. It appears that the current PAC focuses on this content category alone.

"Colorado Model Content Standards for Science"

The Colorado SOLs contain six broad goals (e.g. "interrelationships among science, technology, and human activity and how they can affect the world" or "common properties, forms, and changes in matter and energy") which in turn may be broken into one, two, or three more detailed tasks, which in turn are explained through specific benchmarks stratified by grade block (K-4, 5-8, and 9-12) and not by course.(*68*) The benchmarks cover material found in typical science subjects: physics, chemistry, biology, geology, space and the solar system, and earth science. Relevant transportation facets are suggested; for example, one benchmark involves relating science to technology and lists bridge design as an example.

The standards also contain key unifying themes that may be applied to several disciplines; for example, "interpreting and evaluating data in order to form conclusions", "identifying major sources of error or uncertainty within an investigation", and "explaining the use of technology in an occupation." Certainly this can be tied to future PAC modules, for example, ITS applications require an understanding of various technologies and can serve as an introduction to the diversity of transportation careers.

The Colorado document also cites a strong reliance on national standards, such as the National Research Council's work.

"New Mexico Content Standards and Benchmarks: Science"

The New Mexico SOLs are similar to those from Colorado in that they present general goals stratified by grade block (K-4, 5-8, and 9-12) and fleshed out with specific benchmarks, although only two levels of specificity are given.(*69*) In fact, introductory information for New Mexico's SOLs explicitly states that there are three types of standards: "unifying concepts", "science as inquiry", and "specific types of science content." Examples from the first two types of standards are relatively general: objectives such as "apply the scientific method in daily life within and outside the school environment" as well as "develop causal functional questions to guide investigations" can be applied within the transportation modules, both existing and proposed, if the curricula are sufficiently revised. The New Mexico standards also list specific kinds of information that students must know, categorized by subject: "life science", "earth and space science", and technology and the history of science."

A reading of the SOLs shows that it is possible to identify linkages if one has a specific module in mind. For example, a transportation-related environmental module evaluated the impact of vehicle usage on emissions could be related, to a benchmark for the 5-8 grade block under New Mexico goal number 11. The goal and the particular benchmark read, respectively,

Goal: "Students will know and understand the synergy among organisms and the environments of organisms",

Benchmark: "Analyze consumption of nonrenewable resources based on population factors (birth rate, death rate, density"

Alternatively, this environmental module could be related to goal 16 at the 9-12 grade block: the goal and particular benchmark indicate, respectively,

Goal: "Students will know and understand the relationship between natural hazards and environmental risks for organisms"

Benchmark: "Develop cost-risk benefit analysis in the context of natural hazards and environmental issues (e.g., ozone depletion, carbon dioxide reduction, and global warming"

Clearly one has some latitude in relating this module to the SOLs: one can attach it to the specific types of information shown here or to the more general inquiry-based SOLs.

"Science Standards of Learning for Virginia Public Schools"

Virginia's SOLs have pieces of concepts shown in other states; for example, in the biology course there is a standard that addresses the history of how biological processes have come to be understood.(*70*) Usually the first

SOL in each course focuses on experimental techniques, such as planning and conducting an investigation, repeating experiments, identifying experimental error, and selecting the appropriate instruments. Although not specifically stated within the document, one can infer similarities between Virginia's SOLs and those at the national level.

Generally, though, Virginia's SOLs are specific to each course at the high school level: earth science, biology, chemistry, physics. The majority of the half-dozen to dozen SOLs for each course outline concepts that students must master that are specific to the discipline being studied, such as writing chemical reactions to illustrate and understand the conservation of matter. Even in these content-specific objectives, however, there are principles that can be applied broadly, for example, one of the first chemistry SOLs notes that students should understand concepts relating to units, significant digits, and experimental error. The biology and physics SOLs, respectively, note the need for assessing "alternative explanations and models" as well as realizing "how new discoveries may either modify existing theories or result in establishing a new paradigm."

Using Virginia as an illustration, it is possible to relate new PAC modules to the science standards. One physics standard relates to describing a physical problem in mathematical terms. Clearly a prime example that captures an important aspect of transportation would be the creation of a dual objective function that presents the problem faced by maintenance engineers in state DOTs: how to allocate personnel time between being on call for snow removal duty (heightened readiness but increased expense) and being sent home (cheap but decreased readiness). The New Mexico volunteer who mentioned this scenario indicated that it is a real challenge faced by transportation agencies during inclement weather.

West Virginia "Adolescent Science Education"

West Virginia has a unique system where students all take the same 9th and 10th grade science course, called "Coordinated and Thematic Science 9" (or 10). Then, in 11th and 12th grades, students can take specific courses such as physiology, biology, and chemistry. At first glance, one might describe West Virginia's science standards as being a bit of a hybrid between those shown for Colorado/New Mexico and those shown for Virginia, but closer examination suggests that these are closer to the Colorado/New Mexico concept.

For all courses there are eight broad "themes", seven of which are continuous throughout the courses and one of which is content specific.(*71*) The seven continuous themes are *nature of science*, *scientific attitudes/habits of mind*, *scientific processes/thinking skills*, *laboratory investigations/hands-on learning*, *science history*, *science, technology, and society*, and *computer/technology*. For each course, these themes are fleshed out with several specific benchmarks: for example, "nature of science" asks students to "recognize general limitations of science knowledge" and to conclude that science is a blend of creativity, logic, and mathematics." The eighth theme – "science themes and content" is specific to each course being taught – biology, chemistry, environmental earth science, physiology, and so forth.

One can recognize parallels with national standards or other states' standards. For example, in consideration of the national standards, one of the objectives for physics reads "P.16: design, conduct, evaluate, and revise experiments (e.g. identify questions and concepts that guide scientific investigations…)". This places an emphasis on the scientific process. The physics standards also have specific content benchmarks such as light, optics, gravitation, and kinematics. In fact, if one were to follow the suggestion of the New Mexico volunteers who suggested a PAC module that used materials provided by contractors, one can see that a lesson on reflective properties of signing, including the angle of the sign and visibility requirements faced by DOTs, would fit nicely with both the *content* standard (light and optics) and the *scientific technique* standard (*how* one investigates the best placement of a sign based on theoretical principles or observed data).

"Maryland Science Content Standards"

Maryland's SOLs can be divided into two categories: *scientific techniques*, which are covered in a first goal called "the Nature of Science" and *content*, which is covered in five subsequent goal areas: earth and space, life science, chemistry, physics, and environmental science.(*72*) As was the case with its mathematics standards, concrete benchmarks are given within each goal area at the end of grades 3, 5, 8, and 12. Specific reference is made to national efforts such as the National Science Teachers' Association and the National Research Council, the latter of which is discussed in the next section.

The first goal area, formally denoted as "the nature of science and scientific inquiry, technology, and the history of science" is particularly useful for the PAC because it shows what one state considers to be properties of science independent of content. This means that if volunteers have a particular topic whose content does not seem to fit into a particular subject area, then they might scan this first goal to see if the investigative technique of their topic can be related. For example, suppose a PAC module involves assessing whether a contractor is skimping on the amount of cement required in a concrete mixture. A relevant application would be to compare samples from five different sources and assess whether the contractor's sample was significantly different. Such a module could be tied to benchmarks such as "analyze appropriate data in drawing conclusions" (in the 9-12 grade block). If the subject of statistics is not appropriate for the students, then one could discuss why having too much sand in the concrete mixture weakens the design of the structure; this would be tied to a benchmark for grade 6-8 students, which reads "…summarize data to form a logical argument about a cause and effect relationship…"

The remaining goal areas list specific content-related benchmarks, some of which appear similar to those from other states. Given teachers' and volunteers' interest in environmental issues, the last goal area – environmental science – covers specific issues that can be targeted by PAC modules in the form of policy questions. Benchmarks that concern topics such as recycling and toxic waste can be related to transportation issues such as requirements to use chopped tire in roadways and the routing of hazardous vehicles, respectively.

Summary of Science SOLs

The science SOLs from the five states have differences in organization and variants in emphasis, but specific modules may be related to specific benchmarks. The challenge is in knowing where to look: a PAC module on emissions may be appropriate to either environmental standards or biology standards, depending on the module's curricula. Another valuable piece of information that can be gleaned from these standards, however, is techniques that educators would like to use in the classroom. The national standards can shed some light on this topic.

TRENDS IN TEACHING: NATIONAL SCIENCE EDUCATION STANDARDS

Many of the state standards mention the influence of work that has been done at the national level. Given the PAC's current emphasis on science, a work published recently in that area was examined. The National Research Council points out that "Content is what students should learn. Curriculum is the way content is organized and emphasized…"(*73*) Certainly one can use the national standards as a guide for what content should be taught – indeed there are national standards that relate to traditional science courses such as physical science (e.g. atomic structure, forces, and chemical reactions), life science (evolution, organization of living systems), earth and space science, and technology. One can also review the national standards to get an angle on interdisciplinary science applications, such as "science in personal and social perspectives" which cover issues such as personal risk and the impacts of substances on mood.

In terms of suggesting what students can learn, there is a definite emphasis in the national standards on scientific principles, such as a focus on the inquisitive nature of science examinations. In fact, although they did not specifically cite it as a resource, several of the teachers interviewed suggested that a "good" experiment, regardless of materials, will entail the asking of questions suggested by these national standards. Such questions will include relating what the student knows to classroom observations, predictions, what students think would improve experiments. For example, one teacher asked his students "what do you think will happen" while the national standards pose similar questions such as "Were there any surprises in the data?"

Yet given that states are developing their own standards to which they will hold teachers accountable, it appears more appropriate to rely on specific state standards for specific objectives. The national standards, on the other hand, are able to emphasize *changes* in how the science material is taught. It is logical that if the PAC can focus on these changes, then these would present a way for the PAC to have a foothold into the classroom.

In short, the national standards emphasize certain ideas (e.g. relating specific information with the scientific process and learning how to investigate various phenomena) while de-emphasizing other ideas (e.g. memorizing specific facts). Three trends are directly relevant to the future PAC:

- *Learning science has a real-world application*. The PAC should consider activities that require application of a scientific concept for a real-world problem and then communication of this information to lay people, as opposed to questions that only focus on specific scientific concepts. Another real world task is being given a conclusion and then analyzing data [to ascertain whether or not the conclusion is true] as opposed to a more traditional experiment, where one first synthesizes data and then draws a conclusion. The investigators' interpretation of this might be, for example, to be given a point of view (e.g. seat belts should be on school buses as they would save lives at minimal cost) and then let students defend this conclusion through collecting the crash data, reviewing policy memoranda, and considering public opinion.

- *Organization of information is an essential skill*. The national standards the "management of ideas and information" as opposed to "management of materials and equipment" [presumably in the lab]. This has particular relevance to the social aspect of state DOTs. Volunteers cited issues that arise in the workplace within the transportation field which require this skill: roadway location decisions and the allocation of manpower for a specific task, for example, involve soliciting ideas and information from multiple sources, synthesizing these into a position, and then communicating this result to an audience.

- *Research is a critical skill*. The NRC highlights the role of *practice of inquiry*, going so far as to say that if one replaces this inquiry with statements only, then "quality learning" is lost. For future PAC curricula, this indicates that being able to formulate predictions and ask "what does this mean" is worth including in select modules.

BROADENING THE PAC: TECHNOLOGY AND SOCIAL STUDIES STANDARDS

The original intention of the proposal had been to consider mathematics and science standards only. In light of the interviewees' responses that transportation is a broader field, it seems appropriate to consider standards in related fields, such as technology, social studies, and the life sciences. In fact, given that some schools' representatives have mentioned an interest in multidisciplinary efforts, it would not be farfetched to consider standards in fields like English or economics/accounting, if modules could be developed that draw on those skills that are used in the transportation profession.

For example, Montgomery County, Maryland, identifies several instances of the "core learning goals" for social studies in the state of Maryland that, in fact interface nicely with some of the PAC modules as is. One example is under the first goal "political systems", where suggested content includes "impact of media on public opinion and behavior of the electorate."(*74*) This understanding of how media coverage can affect public perception can readily be tied into the town meeting activity within the PAC social studies module. In fact, the Maryland document identifies a sample lesson plan requiring student research and selection of a stand on some policy issue at the local, state, or national level. The town meeting module can be modified to fit within the bounds of this sample lesson plan.

The same document, even though its focus is on government, makes mention of one aspect that several science teachers suggested should be encompassed by the PAC: an environmental component. Within the third goal (geography), it is stated that "The student will evaluate the role of government in addressing land use and other environmental issues." What is interesting about this document is that it lends credence to the notion that multidisciplinary lessons are feasible: one can envision, for example, students learning about the environment within a science course (e.g. the formation of ozone from NOx and VOCs) and discussing in a government course the role of the various political systems in deciding whether or not legislation is appropriate to regulate stationary source emissions as opposed to mobile source emissions.

Technology is another focus area that is gaining in importance. Sample SOLs were obtained directly from a representative of the West Virginia Department of Education.(*75*) These SOLs cover five specific technological areas: "foundations in engineering", "communications systems", "construction systems", "manufacturing systems", and "transportation systems." Within each area are approximately a dozen general goals and between 30 and 70 specific benchmarks. For example, within foundations in engineering, one general goal and one of the several benchmarks under that goal read, respectively:

Goal: "Understand and demonstrate knowledge and techniques about electronic control and use them to solve open-ended problems from a design brief."

Benchmark: "FIE52: Describe the purpose of input (sensing) devices such as switches, temperature, and light sensors and use them in control circuits."

The DOE representative explained that the detailed benchmarks explain how the general goal may be accomplished; teachers may view the goal as an "umbrella" under which they may meet benchmarks in ways other than the ones cited. This is especially evident in the transportation examples that are shown: for example, two general goals and two benchmarks within these goals are:

Goal: "Apply accurate measurement practices, solve math problems, and perform algebraic computations as they relate to transportation careers", and

Goal: "Apply design, creativity, and critical thinking skills to develop solutions to a variety of problems involving different technologies to meet specific criteria."

Benchmark: "TRN9: Interpret various charts, graphs and drawings used to display numerical data", and

Benchmark: "TRN11: Plan and select the materials, energy, tools, and processes needed for producing solutions to transportation problems, and produce solutions for a variety of problems."

While these examples are specific to transportation, one can also see how the general goals could, in fact, be tied to the surveying and environmental modules suggested previously. Thus the act of designing a roadway's proposed realignment, with sufficient background, could relate not only to the geometry/trigonometry concepts noted in the math SOLs but also to the technology standards shown above.

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APPENDIX D: INTERVIEWS WITH TEACHERS, STUDENTS, PRINCIPALS, AND TRAC VOLUNTEERS

NEW MEXICO SCHOOLS

WEST VIRGINIA SCHOOLS

INDEPENDENT EDUCATOR EVALUATION

DIGITIZED STUDENT DRAWINGS

TABLE D-1: CHRONOLOGY OF INTERVIEWS

State	School	Audience	Dates
Virginia	High School (suburban)	Teacher	Sept. 21
Virginia	Middle School (urban)	Teacher and TRAC volunteer One class of 8^{th} grade science students One class of 8^{th} grade science students Principal (by phone)	Sept. 25 Sept. 25 Sept. 25 Nov. 10
Virginia	High School (suburban)	Teacher	Sept. 28
Maryland	High School (urban)	Teacher One class of physics students	Oct. 26 Oct. 26
Maryland	High School (urban)	Teacher One class of technology students	Nov. 4 Nov. 4
Maryland	Assorted	MdSHA TRAC volunteers (four)	Nov. 4
Virginia	High School (suburban)	Teacher One class of physics students Assistant Principal	Nov. 5 Nov. 5 Nov. 5
Colorado	Assorted	Colorado DOT TRAC volunteers	Nov. 12
Colorado	Intermediate School (urban)	Teachers (two) and TRAC volunteer MESA students (three) Principal	Nov. 13 Nov. 13 Nov. 13
Colorado	High School (urban)	Teacher Principal	Nov. 13 Nov. 13
Colorado	High School (urban)	Teachers (two), Volunteer, Community College rep., Tech. lab rep. (**all together**)	Nov. 13
S. Africa	Assorted	TRAC Manager (by phone)	Nov. 17
Maryland	High School (suburban)	Teacher and Volunteer One class of technology students Principal (by phone) One student (by phone)	Nov. 19 Nov. 19 Nov. 23 Nov. 30
West Virginia	High School (rural)	Teacher Principal One class of physics students One class of chemistry students Four former Physics/PAC students	Nov. 24 Nov. 24 Nov. 24 Nov. 24 Nov. 24
New Mexico	High School (rural)	TRAC volunteers Teacher One class of technology students Principal	Dec. 8 Dec. 8 Dec. 8 Dec. 8
New Mexico	K-12 School (rural)	Teachers (two) Federal Programs Coordinator One class of Algebra I students	Dec. 9 Dec. 9 Dec. 9
New Mexico	High School (urban enrichment center)	Teachers (three) TRAC Volunteers (two) One class of robotics students	Dec. 10 Dec. 10 Dec. 10
New Mexico	High School (private, urban)	Teacher One class of science students TRAC Volunteers (two) Principal NMSHT Dept. Research Bureau Chief	Dec. 11 Dec. 11 Dec. 11 Dec. 11 Dec. 11
West Virginia	High School (rural)	TRAC volunteer (by phone) Teacher One class of physics students State TRAC director TRAC volunteer (by phone)	Dec. 3 Dec. 16 Dec. 16 Dec. 16 Dec. 29
West Virginia	Department of Education	DOE Representative (by phone)	Jan. 5
Maryland	Assorted (by phone)	Former TRAC Student (by phone) Former TRAC Student (by phone)	Jan. 21 March 17

VIRGINIA SCHOOLS

Teacher from Virginia School 1

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs.

- The instructor is a biology and environmental science teacher who has taught TRAC for several years, and currently is the only teacher in the school teaching TRAC

- Enthusiastically trying to sell TRAC to physics teachers. They will try the motion module this year. Has not promoted it with math teachers

- Participates in the CHROME (Cooperative Hampton Roads Opportunities for Minorities in Engineering). This program encourages minorities and women to pursue a career in engineering.

- Regarding support, no TRAC volunteers have visited the school although a new computer and PAC arrived in September 1998. Additionally, there is some confusion as to whether the fall 1998 TRAC requirement of six activities means that six modules must be taught or six activities must be taught, noting that a single module such as social studies may contain multiple activities.

- The instructor became aware of the TRAC program through a National Science Teachers' Convention a few years ago sponsored by Drexel University.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

Overall, the instructor notes that the current PAC is mostly limited to physics applications in terms of the type of information that is covered. Several aspects would improve the *student manuals*, the teacher's manuals, and the specific modules that have been used: social studies, sound, SimCity, and an activity from the bridge module.

Improvements for the Student's Manual

- Use worksheets rather than text only. For example, replace a lot of the text and questions with worksheets and insert worksheets that can be photocopied directly by the teacher. The worksheets should be more like a lab report, so that students could collect data in a well labeled data table, record results, and hand it in as a lab report. Handouts should be graphically enhanced

- Use figures and diagrams more often. Add bigger and more interesting print throughout, although color is not necessary since photocopying is in black and white.

- Consider the national 4H council format, where tiny booklets are used.

- Give instructions in the form of a *problem* and *hypothesis* that match the Standards of learning. For example, if a student needs to collect some type of sound data, a worksheet with a table and shading can be easier to understand than text instructions.

- The two columns in the manual may be confusing as some schools emphasize a technique called “two column note taking” with major topic headings on the left and detailed information about those topics on the right. Hence have a teacher review the manuals before distribution.

Improvements for the Instructor’s Manual

- Instructor materials daunting to teachers considering it for the first time. Too long and complex. Looks like too much preparation work

- Each module should have the subject area (biology, environmental science) and the portion of the standards of learning (SOL) requirements it meets prominently at the top of the first page, as explained in the section that discusses SOLs

- Add equipment setup diagrams to each module or activity, not just one in the front of the notebook. Add experimental diagrams to both the instructors’ and the students’ materials, along with variation in typefaces and type sizes and styles as noted previously.

Social Studies Module

The chief benefit of this module is that it gets the students thinking about key issues. It can be fit into a reasonable amount of time–generally an hour of preparation. The town meeting component, for example, can be done in one to two hours; the entire social studies unit might be done in a week.

Sound Module

This module is useful for teaching concepts, especially data collection. The immediate response–e.g. students make a noise and know its decibel level–is rewarding, and this phenomenon can be tied to the real world that the student experiences, such as rock concerts. Hence the sensor probe is very helpful; allow about half an hour for preparation.

Bridge Activity Module

This module ties in to experimental design and the scientific method very well, even though the material is not environmental or biological per se.

SimCity Module

This module is a hit from the start; students like the interaction and view it as a game rather than as something they are learning. With only one computer, SimCity might be a reward for students who finish another activity early; but it has to be an individual activity. If SimCity were available over a network, which is not presently the case, it could be used over a 2-3 day period so long as one outlined specific tasks for the students to accomplish.

PC Solve Module

This module is not used given that the material is outside the scope of the class, there is only one computer, and there is a lot to learn for an application that will only be used a small amount of time.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

This teacher actively sought out additional materials that are useful for involving the students more directly in the classroom. One successful example is an activity booklet published by the 4H council that has both a transportation and an environmental component. The booklet is more geared towards the intermediate school level; however, many of the applications may be appropriate for an earth science or physics class at the high school level. The two chief benefits of this 4H booklet is that it present materials graphically (rather than just with text) and it has simplified experiments that don't require many materials or preparation time thereby making them easier to use in the classroom with student lab groups.

Successful educational aids are highly interactive**–that's more important than being high tech.** One example is a scavenger hunt for transportation topics; a way to do this is to search for information on the Internet. Games or an activity where you design or create are popular as well, such as drawing cartoons or even making collages. In order to broaden the TRAC audience, increase the amount of interaction in the activities. Examples of other types of activities are mini-plays and questionnaires, as students are opinionated and they enjoy making up surveys. In fact, one can tie activities to vocations which the students enjoy: in the case of surveys, for example, present it to the students as "you are a market researcher"; another type of vocation is detective work: "you are the forensic specialist who must interpret what happened during this car crash." In this latter case students might even make up their own story board to describe the events at the scene of the crash. Kids are fascinated with the morbid!

In the best lessons, the emphasis is on the activity not the physical educational aid. For example, ideal hands-on experiments in the area of pollution include placing Vaseline on slides and making observations one week later, growing and observing plants, or filtering various water sources with a coffee filter to measure pollutants. Students like to make things, and using artwork is one way to bring a student into a field if that student's natural talents are in that area.

Generally, an activity or instructional aid will succeed if it meets three criteria:

(a) it fits well with the state or national standards of learning,

(b) is user friendly for teachers and students, and

(c) it contains materials a teacher can readily acquire, it will succeed.

A great way to accomplish (c) is to contact teachers before developing a module and consult with them as to which materials their school can provide. **Regarding (b), kids love hands-on activities with immediate or instant feedback.**

The *worst lessons* include activities that require too many parts or that are exceedingly complex will tend not to be used.

The scheduling environment is significant: some schools are on block schedules where you might have students in a subject area for a couple of hours at a time, whereas other schools are still using one period per subject each day. With a 50 minute class, one then can allow about 15 minutes for a hands-on activity after which the students are asked to derive their own conclusions, 15 minutes for discussion, and a 15 minute summary. On the other hand, a block schedule is ideal for many of the PAC modules, and schools are leaning in that direction.

Finally, a caution on using the PC is that some students are intimidated by it – either because the PC is new to them or, if there is only one per classroom, the student may tend to remain in the background in a large group.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

The state standards of learning (SOLs) are increasingly becoming a critical guide in the classroom because teachers must ensure that students can pass standardized national and state tests that are based on these SOLs. In fact, a school report card may be generated based on these test scores. A teacher generally cannot accomplish every item in a program of studies (POS), so he or she must pick the items that fit the SOL. Likewise a teacher would never do an entire PAC, so in evaluating which PAC modules to use a teacher will ask the following questions:

(1) Is the activity or experiment easy to set up?

(2) What will the students get out of the activity?

(3) Does the activity meet an SOL?

(4) If not on block scheduling, will this activity be accomplished as a series of quick activities done in small groups simultaneously, as a class demonstration, or with different stations where students take turns at teach station?

(5) How would these activities tie into a teenager?

With regards to item (3), the instructor's guide is helpful but it could do a lot more; namely identifying (a) which type of class is suited to the module (e.g. physics, social studies, etc.) and (b) what type of *skill* is taught by the module. Note that item (b) does not necessarily indicate the type of information in the module, but instead the skill. For example, a module based on Newton's law of motion contains information that pertains to the expression force = mass * acceleration; yet the module might teach valuable skills that can be applied broadly, such as data collection, experimental design, interpretation of results, and other components of the scientific method. As yet another example, the bridge building module will be taught in the AP Environmental class because the lessons of the scientific method are transferable across the two disciplines. Items (a) and (b) should tie directly to standards of learning for the particular state.

IDEAS FOR FUTURE PAC MODULES

In Virginia, other PAC modules should include not only an interface to a PC but also an interface with graphing calculators and the CBL (Computer Based Lab) standard. For example, one can attach the Vernier probes directly to the CBL or graphing calculator; in Virginia each student is given a graphing calculator, which means software that operates on only one PC (and hence requires a class demonstration) could be transferred to a graphing calculator (thereby allowing each student to perform the activity.)

Several subject areas should be included or expanded:

- *environmental concerns*, especially air quality. It is recommended that advanced placement (AP) workshops for AP Environmental Sciences be examined, to see what types of lessons could be included in the curricula; specific foci include exhaust emissions, air quality modeling, and measuring the diameter of the tailpipe. One can tie in health impacts on humans, such as airplane noise, and physical relationships, such as changes in pressure and height.

- *vocational activities*, such as the "tech prep program" where schools are being given grants to develop students' interest in other careers and to learn some of the fundamental concepts that are used in these careers. Both the Ford Technician Training Academy and the Cord (Center for Occupational Research and Development) should be consulted for ideas.

- *maps on the Internet*, which brings in a GIS component as well.

- *social studies*, where there are no right or wrong answers. Again, this module may be slanted towards environmental science as well.

The best instructional setting is hands-on, using data sheets, with lab groups of no more than four people, and using experiments that require (in Virginia) a graphing calculator which all students have as opposed to a PC.

Teacher and Volunteer from Virginia School 2

In this particular case, both the volunteer and the teacher were interviewed together. For clarity, these comments have been grouped when appropriate; for example, in tandem both persons suggested improvements to future PACs. The volunteer also mentioned some items that are clearer if left on their own; these are presented separately to capture the volunteer's perspective.

BACKGROUND INFORMATION FOR THE VOLUNTEER

The volunteer works about four hours away from the high school but commutes there to facilitate TRAC activities. He sees his job as helping students make the connection between TRAC and the real world (and his job at the state highway department). The volunteer noted that it is his responsibility to relate real-world examples to the PAC while the teacher would have the job of deciding which PAC modules should be covered. The volunteer sees a direct correlation between his job at the DOT and his job as facilitator. In fact, he has participated in the recruiting of facilitators. He has talked to the students on the subjects of movement, momentum, velocity and crash evaluation (speed vs. severity). He has also discussed his interactions with public officials and community groups, which are similar to activities used in the social studies module.

GENERAL COMMENTS FROM THE VOLUNTEER

The volunteer would like to see a traffic simulation model included in the TRAC modules, along with a real world update on traffic related topics. He has shown the students how traffic signals work (most had a pretty good idea even before his lecture), including inductance, signal timing, and determining how strong the mast arm must be to support the number of signals on it. He has shown the class how speeds are measured with radar and covered topics such as site distance, reaction time, and the relationship between velocity and the force of impact. By using work-related examples, he has explained how everything can be explained by science and mathematics.

Similar to the teacher, he tries to use interactive, discovery learning in his interactions with the class. He gives them as few actual answers as possible and let's them figure things out for themselves. He also introduces the concepts of cause vs. effect and feasibility in his discussions.

He also mentioned that some teachers have been concerned that some of the TRAC activities are hard to set up and sometimes don't work. Sometimes there are tricks to making a module work, and teachers have to improvise. For instance, in the force experiment, some portions of the roadway had to be propped up with books in order for the experiment to function properly. To help familiarize teachers and TRAC volunteers with the activities, VDOT is establishing a TRAC room at the central office, where equipment necessary for each of the modules will be set up.

BACKGROUND INFORMATION FOR THE TEACHER

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs.

- It is acknowledged that TRAC must be used six times per academic year, which encourages teachers to adapt it to their lesson plans. In this case, even though the PAC was not received until January 1998, by the end of the 1997-1998 school year all modules in the PAC had been used except social studies. (The social studies module was not used only because of time limitations and the teacher expects to use it during the 1998-199 school year).

- The teacher has 8th grade students. One way of reaching former students is to contact the two high schools that they currently attend.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

Instructor's Manuals

The instructor's manual is fairly easy to use and supports the student's manual, but it is more complicated than it needs to be and should be arranged stepwise. Every lab should have the purpose and scientific steps listed clearly.

The impulse momentum module is difficult to use, but the revised version that is becoming available this year may be an improvement. Overall, much of the equipment was difficult to use and unreliable according to the volunteer; very few of the experiments worked as intended. For example, regarding the force probes, one would need to know which ports (A,B, or C) are necessary. Most troubling about this is that when the experiment does not go as intended or when equipment breaks, students tend to panic.

Overall, it cannot be assumed that students will know keyboarding, even though they are taught this in the 5th or 6th grades. More PCs in the classroom would be a plus.

Magnetic Levitation Module

The use of Styrofoam cars was one of the biggest hits in the past year when almost the entire PAC was used. The students brought their own Styrofoam from home and bought their own magnetic strips. The teacher noted it was helpful not to show the students how to design their cars and track but instead to let them experiment on their own; for example, some students first used track that was too long, then too short, then of varying lengths, until they learned it must be balanced. A disadvantage of giving the students a model from which to build is that they may duplicate the model you provide. The highlight of this module is that by far it was the most interactive.

Improvements for the Student's Manual

The student's manual could be made much simpler by teaching students a process rather than giving them step-by-step instructions. Given that groups of 3 to 5 students would work together, it is easier to give the students basic instructions such as "read, scan, and interpret what needs to be done" or "discuss the procedure before giving it to me." In a 48 minute class, one needs to have some basic checkpoint questions to keep everything on track; for example one might ask:

(1) What do the students know before they begin the experiment?

(2) What do they want to learn? What needs to be read or discussed?

(3) What did they learn after performing the experiment?

Block schedules are helpful for performing the experiments as two periods gives enough time for some of the activities in the modules.

Instructor's Manual

The instructor's manual is easy to use.

SimCity Module

The key question a teacher can ask is "What does a city need to function properly?" This gets the students thinking about the types of services a city needs, and it further piques their interest when they hear that actual cities are using this software in the real world. No handouts are given, instead everything is done incrementally. (get more from Cheryl on this). Overall, the students really enjoy SimCity and even sign up for it on their lunch hour.

PC Solve Module

This module works very well when asking students to figure out for themselves what the various components of the activity mean. For example, with respect to graphing, students can be asked the following questions in series:

(1) What does the *x* axis stand for?

(2) What does the *y* axis stand for?

(3) Therefore what does the graph indicate?

In fact, sometimes a debate will arise when students within a group disagree about how to proceed.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other *types of aids* ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

One type of approach that the volunteer emphasized is being able to quickly relate current events in the news to the PAC. For example, an approaching meteorite may illustrate physics while a story about a man who was killed by a remote control stereo fascinated the students.* Issues relating to wetlands mitigation may be included as well. The volunteer typically has about an hour to discuss this information.

The teacher noted that what works well is to give the students as little information as possible and then let them be creative in finding a solution. This can be accomplished in a number of ways:

- Have the faster students train the slower students. This keeps the faster students occupied and prevents the slower students from being left behind.

- Make the students discuss a problem amongst themselves in small groups (of 3 to 5) before they can request guidance from the instructor.

What should be encouraged?

- Labs that have a purpose and objective should be encouraged. Additionally, a well-prepared experiment is one that will work the best; hence experiments should be easy for the teacher to follow.
- Use materials that students can physically manipulate with their fingers. An example is where students make their own lotions and bath salts, which is especially popular once they know about some of the harmful ingredients in commercial products. The students vary the ingredients themselves and manipulate the substances by hand, which they enjoy. This ties in with the unit on acids and bases as well.

- Activities that require brainstorming can be successful, although the instructor has to constantly monitor groups to make sure that all members are participating. Left to their own devices, a group of five students might have only two or three active participants.

- Use activities that are hands-on.

- Labs should be easy to set up–5 minutes at the most (or a little more the first time).

What should be avoided?

The following types of activities should not be included in the classroom!

- Dangerous activities. Labs that require too much supervision or that have any risk should be avoided. For example, in schools the gas jets have been turned off and only Bunsen burners are available.

- Labs that don't work. Some TRAC modules are difficult to set up and some don't always produce the right results. In the motion module, sometimes the cars get stuck, defeating the lab's purpose.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

* The full story is that during a contest where the objective was to build the loudest car stereo, a leading contender had a stereo so powerful that he had to operate it with a remote control some distance away from the vehicle. The stereo stopped functioning, so he went to his car to see what was the matter. In the course of doing so, his stereo suddenly started working and killed him. Although a morbid story, the volunteer noted it captured the students' interest and drove home the point that sound is basically a form of pressure that in this case stopped the man's heart.

The 8th grade curriculum in Virginia depends heavily on meeting SOLs; in fact, some of the newer textbooks explicitly state which SOLs are met by the text. Adherence to the SOLs is very important, especially in the eighth grade classes, which are about to be tested to determine if they can move on to high school. The teacher points out that the state Department of Education hasn't aligned the eighth grade science curriculum to match the SOLs very well.

Measurement is a fundamental concept that is emphasized in the SOLs: measuring height, width, area, weight, light, sound, and other dimensions is significant. Additionally, graphing and multiplication are included.

With respect to *chemistry and other aspects of science*, students need a firm understanding of acids, bases, and various forms of pollution. This could be incorporated within the PAC; for example, study the properties of materials that best absorb sound.

IDEAS FOR FUTURE PAC MODULES

The TRAC volunteer noted that there is a direct correlation between the PAC and his public involvement efforts within the traffic engineering division. This places a heightened importance on the role of social studies. Because of his familiarity with accident reconstruction, the modules on impulse, momentum, velocity, and acceleration are a nice fit as well. The teacher noted the importance of *versatility* within the modules because a teacher may change grades and subjects from year to year, hence it would be beneficial if knowledge of PAC modules could be widely applied. Both the volunteer and the teacher recommended several additions to the current PAC:

- *Tutorials from traffic simulation models*. For example, the animation sequence of CORSIM can be shown to students and accompanied by an explanation as to what the car movements mean.

- *Real world explanations*, such as how a traffic signal works, what comprises a structural analysis of a utility pole, and the theory behind radar for verifying speeds, can enhance students' interest. **The key is to take these examples and relate them to the basic lessons in the PAC**; for example, the relationship F=MA is a basis for some of the types of structural analysis.

- *The future of transportation*. Much of the ITS (Intelligent Transportation Systems) concepts would fascinate students who otherwise view transportation as highways, bridges, and a few video cameras. For example, automated steering, GPS-based navigation systems, materials science, and smart travel (ITS) are eye-opening topics.

- *An environmental component*. Note that science is not just chemistry and physics but includes the environment, botany, biology, archaeology, and geology. If these can be tied into the PAC it would be very useful. Also note that environment means not just air quality but water and noise pollution as well, such as properties of sound absorbing substances. Students like to talk about what the environment will mean in the future, and the teacher tries to tie studies to what the current administration is doing or not doing. For this generation of students, their whole lives will involve conservation of resources and air and water pollution. The SOLs for the 8th grade curriculum are heavy on pollution chemistry (acids and bases, chemical reactions). He tries to tie the student's studies of the environment to what the current administration in Washington is doing. For example, since for every acre of highway construction a certain number of acres of wetlands must be set aside, such conservation efforts could be part of the TRAC modules. An interface with the life sciences, maybe in terms of erosion and botany (using plant life to filter out chemicals produced by road construction or roadside plantings) would be appropriate.

- *A computer basics module*. Some students are intimidated by the computers, especially those who don't have PCs at home. Making an optional computer module available to these students through TRAC might be a good idea, and if it were "fun" enough, maybe all students would want to use it.

Students from Virginia School 2

Before the interview with the teacher and TRAC volunteer, the investigators walked into a classroom with eighth grade students who had some experience with the PAC. Over the course of two 48-minute periods, two classes of students were asked what they thought of the TRAC PAC. Their oral responses are shown below.

Afterward, students were asked to write down what improvements they would make to the PAC: they could either indicate something they liked or something they disliked. Names have been included where the students so desired, although some preferred to remain anonymous. These written responses have not been edited but instead are presented exactly as they are written.

FIRST PERIOD CLASS BACKGROUND

The students had very recently completed the PC-SOLVE activity and had been shown several of the others, including the Maglev and sound modules. Initially, the first period students had some difficulty remembering what TRAC was and what the activities were (or at least they had difficulty in expressing what they remembered), but after answering some preliminary questions about transportation and VDOT, they remembered quite well.

As an introductory exercise, the students were asked what they liked and disliked about school. Some of their general likes and dislikes were reflected in some of their later comments about the TRAC modules.

ORAL COMMENTS RECEIVED DURING THE FIRST PERIOD

One student opened the discussion by saying that there was too much keyboarding in the PC-SOLVE module and that the students didn’t like writing. Another student mentioned that she liked the multiplication part of PC-SOLVE because she liked math in general. Another student liked “the whole thing” because it was a challenge. She liked following the directions and not knowing what would happen at the end of the activity. She liked having to “use her brain” to figure it out. Several students later mentioned that they had to work to figure out what the directions were telling them to do. They also didn’t like that five students used the computer at once (there were two computers in the room) and that they had to do other activities while waiting to get on the computer.

Several students also like the fact that graphics were used in PC-SOLVE, but thought that there should be more visual things (“like pictures”) in the activities and better graphs. (One student asked that dogs and cats be included.) They also thought that more games should be included, like a car game that would deal with the problems of driving and where players could score points with route choices. These were continuing themes.

In terms of improvements, the students wanted the activities to be more hands-on, wanted to use the computer more, wanted more and better visuals, and more things that they could move with their hands or make move with the mouse. They wanted activities that were more entertaining (“not boring”).

They commented more than once on the directions. One student asked that the directions be made more simple, and everyone seemed to agree. They also asked that the instructions be numbered and be straightforward.

When asked what they thought should be added to TRAC, they had some interesting ideas. One student thought that something on highway construction should be added. Several endorsed that addition of maps, with latitude and longitude. Another student asked for 3-D graphics. The class had not done a social studies module, but one student wanted activities where they could do skits and play other characters (Her reference was another class where students portrayed historical figures). Another suggested that sports be incorporated in some way.

SECOND PERIOD CLASS BACKGROUND

The second period class seemed somewhat more advanced than did the first period class, and they were somewhat more forthcoming and articulate. They seemed to have a clear idea of VDOT's role and the breadth of its functions, mentioning improving streets and highways, building and maintaining roads, fixing traffic lights, putting up highway signs so people "knew where to go," fixing pot holes, preventing traffic crashes and clearing the crash scene as soon as possible. It is possible that this class had been better "prepped" by the instructor than had the first period class.

ORAL COMMENTS RECEIVED DURING THE SECOND PERIOD

The class remembered that they had been shown SimCity, the Maglev module, and the motion, sound, and energy modules (there was some disagreement as to which modules they had actually seen). They specifically remembered seeing different probes used to measure sound and movement, using magnets to find new ways of traveling, to keep cars on the road, and to avoid crash scenes. Although someone said they hadn't done the sound module yet, several students remembered talking into the blue box and seeing different sounds on the screen, and seeing how sound travels. They particularly liked testing the frequency and pitch of various sounds. When asked which module was their favorite, 11 mentioned the Maglev module and 4 mentioned the motion module. They treated the Maglev concept almost as if it were magic, with some students mentioning that they hadn't realized how powerful the magnetic force was in moving things around on the table, moving things apart and attracting things. In terms of motion, they liked seeing the "different pictures on the screen" and "seeing the infrared." The energy module was last in terms of preference, because it sounded "boring" and couldn't compare to the sound or movement activities.

They were then asked to describe "boring" activities they had done or could imagine doing in school. Some of these included sinking a baby pool to make a pond, looking at bark under a microscope, just getting lectured, writing a book about fractions, sticking a needle in the back of a fish's head and waiting for it to move, and science fairs (research and writing). When asked to describe "fun" activities, they mentioned doing special projects where they could pick and research a topic of their choice, dissecting frogs, writing sand starring in their own opera where everyone had a specific job, turning cow eyes inside out and touching the pupils, finding ways to transport eggs without breaking, working on an airplane in groups of four people, acting out any part of history they wanted, cutting open a soda bottle and making a rainforest, building cars out of Lego blocks and racing them, and making and launching their own rockets.

When asked what they would like to see in a TRAC program of their own making, they mentioned the following:

- more eye catching graphics, more colors
- making things, like cars or roadways, that they could make out of wood or Styrofoam
- having everything be hands-on with not so much reading or paperwork. (Don't have them read about a thing on a sheet of paper but take them out to see what can be done. Let them touch everything.)
- seeing how roads are actually built and let them use materials to build a small road
- more games, like putting a highway on the computer with red lights, with cars they can drive, and with police to pull people over
- using virtual reality in the modules or having a virtual reality module

STUDENT ESSAYS FROM PERIOD 1

If I was going to build a new TRAC-PAC I would put more game like how traffic works. Show were you put the casma and how they work. A game like how you work as research scientist so you can see how it is like.

If I could blid a know Trac-pac I would put 9-D pitcher and 3-D games; would put 3-D fish on well; love hunting so, would love to put a duck hunting game in it and have pitchers from the 1870 so people can see what it was like back then and I would have written under is to tell what happened back then and they can learn from it and tell there parents about it.

To me I would make more typing involved. I would put more thinking involve something like critical thinking and less directions.

One thing I would remove is all the activities and put in educated things in like math, science, S. Studies, English all kinds of educated things that would get me out of trouble.

If I were to redo Trac-Pac I would simplify the directions. I think they are to exagerated. I think if they were simpler it would be easier to follow.

One thing I would like to add was 3D graphics of how to drive and set up a car or truck or any automobile or place.

If I would build a Trac-Pac I would add more maps telling and showing the traffic. I would put a lot of drawings on the maps. I would make manuals telling the easiest way to get to traffic.

I think they should make the next Trac-Pac with 3-D music people. I will make it more interesting it will be like videos in the peoples cars.

If I could put this on the Trac-Pac I would put maps on that how to building. And show it in 3-D.

Add 3-D pictures. Change–make clearer instructions. Remove–science part.

I would put a sports center in the new Trac-Pac because most young people love sports these days.

I would put 3-D graphics that caught the persons on that is on the computer. How do I caught the person eye by making people, things, cars etc., to caught the person eye. I would put a mic to talk into the computer instead of typing of the time.

I will add a lot of pictures, sports, graphics, and directions 3-D graphics.

If I were to redo the Trac-Pac I would have it in 3-D so that like when the had the war back then you could see what the other people was doing and how the person shot ___________.

If I were going to build a new Trac-Pac I would add new graphics so the teenagers could have fun.

I would add more information and better graphic so that people can understand and see ir more better.

If I was going to build a Trac-Pac, I would put graphics and picture on it. Like have a car with a radio and the radio is telling where accidents are, and you have to get to a designated place within 30 minutes or so. It would have a map to help you figure out where to go.

If I was going to build a new Trac-Pac I will add some 3-D driving games. I will also take off some of the directions.

If I was going to build a new Trac-Pac one thing I would add is a website that people could join and learn about the Trac-Pac. Every person that joins should have their own password to get on. That would be neat.

I would have Sinclity 2000 or 3000. I need to change the direct to a shorter list.

I would put 3-D graphics with two cars that crash into each other. Then you should make a map with a point that where the two cars crashed at and the person would have to fined where it is on the map.

One thing I would add is more entertaining things. The person using the computer be more interactive with the system. Another thing is don't have so much math problems. It makes it more boring. More pictures or music too keep the person entertained. More uptodate things would be better for the teenage mind.

STUDENT ESSAYS FROM PERIOD 2

I would add a rule that you would have to have at least 4 trees per half mile. I would also reduce the construction.

I would keep the magnets, sounds, and movement. I would remove energy. I would add color and virtual reality.

I would add materials to build minigher roads in a model city. You would have to control traffic with stop lights and organized roads. Also, you could add guardrails on steep hills and sharp turns or even speed limits if the cars were controllable. You could have accidents to clear up and road hazards that really exist in life. Like pedestrians and drunk drivers.

I would make TRAC-PAC more eye catching, not to just have black and white but to have colors like the rainbow.

I would add a hands-on project where you have to make a roller coaster. You have to build it with wood and it has to really run, whether by something like magnets or just by a push.

I would add a good hands on activity. Like making and building your own airplane and of any materials you'd like. Because it would be your own creation and idea.

If I was going to build one new thing about TRAC-PAC I would put less reading material and a lot more hands on materials just so I could have more experience and more activities.

Add ideas how the regular person who drives on the roads can improve how VDOT can fix roads. One question I have is why is it taking so long in fixing interstate ______ . You are doing a good job thank you.

Make computer graphics more bright and colorful. Make things 3-D because personally I would rather play with bright attention grabbing graphics than with plain and simple black and white screen set ups. More visits from VDOT with doughnuts.

One thing I would change on the TRAC-PAC would be to actually build a city with legos or other building materials; a real SIM city 2000. It would have roads and buildings and somehow, the cars would run electronically down the tracks. P. S. Thanks 4 the doughnuts!

I would make the TRAC-PAC more technolized. I think I would remove the energy module. I would also make it more hands on. Thanks for the donuts!!

One thing I would change would be put more ________ activities like _______ games like driving on bad roads. I would also add building to scale models. PS Thanks 4 the doughnuts!

I would add more 3-D stuff and make the roads and cars more realistic to make it feel like you're actually driving a real car on a real highway. I would also make the screen more vivid and for day make it light and night make it dark.

I would add a computer game were you could see your self build a street. It would give you options of different roads you could build, were your road would be. How long? How wide? Etc. It can't take but so many days also. If it is completed in the given days points will be received–you can begin on a new one. Thanks for the doughnuts.

I would add a sound wave airculator where you could see what would make a certain sound. It would be a real experience.

One thing I'd change in the Trac-Pac would be to change everything to hands on. Instead of reading something on a sheet of paper I would rather have it all hands on. It would be more fun and the students would enjoy it more than reading it from a sheet of paper. Exampple: Instead of reading what the Trac-Pac is you would be able to touch everything in the box instead of reading it.

I would put a driving simulator on the trac-pac so young people can learn to drive in every classroon. With realistic drivers and traffic signals. You can even receive a speeding ticket.

You could add an activity on building an actual miniature road, using the actuial materials or similar materials used in building a road or street. It would show them what they do through the process of building a road or street. Also, it may show students who thought they were not interested are interest in this field.

If I were going to build a new TRAC-PAC then I wouldn't change a thing, because from what I learned I like it just the way it is.

If I were too make any new adjustments to TRAC-PAC I would have more representatives like Mr. Miller, Mr. Haynes, and Mrs. Lynn go around to schools and make video games so they could educate others who are growing up and want to work as a VDOT representatives.

We'd add a video game to see what kind of car would drive the best on a magnetic road. This would be good for people who are doing reports or projectson roads, highways, and VDOT.

Make a jack in the box that gives of heat. Then look at it through the heat sensor.

I would add games to simulate different things on the computer. The games would teach people about driving and the things that they're not supposed to do with what they are supposed to do. I would also add something that would teach them when it is and when it isn't safe to drive.

Principal from Virginia School 2

The purpose of the interview with a principal is to identify generally the factors that affect whether or not an educational aid, such as the TRAC PAC, will be used by the school. Hence the principal is able to offer insight from an administrative angle.

FACTORS DETERMINING WHETHER AN EDUCATIONAL ACTIVITY IS TO BE USED

The principal's role in determining whether new educational aids, programs, or curricula are adopted in his school may differ from the role of other principals for two reasons: *First*, his school stresses "the basics" because they see their major objective as being to teach the SOLs and prepare their children for the High School Assessment Tests. Thus, they don't adopt many "extra" programs, because ensuring that the SOLs are taught is time consuming, especially when some students are performing below grade level. *Second*, Churchland School has recently created a School Improvement Team, consisting of teachers, parents, students, and administrators. This group helps in making many decisions concerning new programs and reflects, in part, the feelings of the community. Thus, Mr. Gray* has flexibility in adopting new programs and would be willing to experiment with them as long as finances are available and the community's sentiment dictates a need for the program. Once someone comes forward with a new program, the School Improvement Team meets and if they agree, teachers and other specialists in the discipline involved meet and make a recommendation to their Director concerning implementation.

TECHNOLOGY CONSIDERATIONS

In terms of technology oriented programs, the school also has a group of volunteer Technology Retirees. These individuals have access to surplus equipment from the nearby naval yard, and they can often help in obtaining equipment needed for computer labs and other programs. It is largely due to the efforts of this group that Churchland has acquired a second computer lab, also equipped with networked PCs. The school has recently arranged for Internet access, but the students will not be allowed to use the Internet until they returned a permission slip signed by their parents.

* Not his real name.

Teacher from Virginia School 3

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs.

- The PAC modules are used primarily during the second semester in their entirety. Throughout the year, however, different pieces of the equipment are used in conjunction with other non-PAC activities: for example, the motion detector materials (software, computer screen, and hardware) are used with an experiment that was designed many years ago but which captures the students' attention.[*] As another example, the sound module components may be employed with tuning forks and an oscilloscope.

- The teacher loans out some of the PAC materials, such as force probes, to other classes; she is also trying to interest other math teachers in the PAC.

- This physics teacher has primarily 11th and 12th grade students and uses TRAC primarily on Fridays. This is her third year with the TRAC program.

- A TRAC volunteer came to the school once the previous year during the magnetic levitation module. That particular day, the classroom was chaotic as the students were building their Maglev vehicles. It was suggested that this might be part of the reason the TRAC volunteer never returned. Yet also some clarification of the volunteer's role would be in order. In this case, had the volunteer persevered, the next session would have been more orderly.

- The teacher heard of the TRAC program through some literature that came to her school. She filled out the enclosed forms and got more information. (She also had an inside scoop since her husband works for the state highway department.)

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

There are four major disincentives for using TRAC and a fifth possible disincentive.

- One setup is required for an entire class of 28 students. Ideally it would be better if one could have group sizes of 2 to 4 people (e.g. via six networked computers) rather than a single group of 28. Because there are so few computers, students only get 15 minutes on the machine. If there were one setup per class (i.e. multiple PACs as well as multiple computers), then there would be no need to rotate student groups and the modules would be much more manageable timewise. (This is even more crucial for younger students, who need more activity and more feedback during class.)

- A lot of setup and teaching time can be required. The first time you go through a module, you might spend an entire block (two periods) learning what needs to be done to make the experiment work. TRAC labs take much longer than other activities in this regard. Many teachers just don't have the time to devote to TRAC, even though the activities are good ones.

[*] In that module, written originally for an Apple IIe computer, students have to walk in certain directions in order to replicate various graphs that have distance on the vertical axis and time on the horizontal axis. The experiment is interesting in that AP students find it much more challenging than regular students, because the concept is less abstract and requires a stronger understanding of the link between real world events and theory.

- The teacher noted that the PAC does not have the flexibility to incorporate new topics.

- A lot of the TRAC equipment does not work or is not appropriate for the experiment at hand. The activity that employs Newton's 2^{nd} law, for example, is tough because the force probes are so sensitive that they pick up on too much environmental noise, which throws the experiment off. Teachers need to know that their TRAC labs probably will not work the first time and that they take longer to set up.

- The item above sometimes could have a positive effect in that you can show the students that it is acceptable to make mistakes, but for some teachers the activities are intimidating because the students will know more about the material than they; in short, the students will show up the teachers.

On the plus side, students love doing creative things. They like hands-on activities and like to use unusual materials. They sometimes are surprised with how well they do the TRAC activities, even if they have no intention of going into engineering. The teacher suspects that different aspects and activities of TRAC appeal to different levels of students. For example, students in the regular classes tend to be concrete thinkers, whereas advanced placement students are more conceptual but may lack common sense.

Improvements for the Instructor's Manual

Overall the manual is very helpful, however, two items would make it better:

- a *troubleshooting supplement* for the instances when equipment does not work as well as it should.

- a statement about *what schools should provide*. For example, schools should be willing to provide a noise source for the sound module.

Magnetic Levitation

The magnetic levitation module is by far the most fun for three reasons. *First* the students design and build their own creation; it allows the students to be imaginative and they get very excited about the design aspects of the module. They are impressed with the strength of the magnetic force and like to vary the placement of the magnetic strip to see how it affects their vehicle. *Second*, they have never seen an application where there is a floating car held up by air (and the magnetic strip). This type of futuristic application gets students thinking about how transportation may change and broadens their horizons beyond roads and bridges. *Third* there is intense competition to see who can get the best results. Additionally, the students are often surprised that this solution is too expensive to be used for public transit. The teacher likes that aspect of TRAC where students have to take cost into consideration when looking at transportation options.

Generally, one wants to allow about one block (two periods) to make the car and one-and-a half blocks to improve the design of the car.

Motion Fundamentals

The velocity/acceleration component is very useful.

Bridge Activity Module

This looks promising.

Sound Module

The sound module had made an impression on the students as they can see a representation of sound, in the form of a wave, on the oscilloscope.

SimCity Module

This module is used very little.

PC Solve Module

This module is written below the level of the students. Additionally, the materials contained within PC-Solve repeat what the students have already seen with their graphing calculators in their math classes. Hence using this module, especially at the beginning of the year, would give them the impression that all TRAC modules are too simplified and repeat basic lessons that have already been acquired. The challenge of using TRAC is to keep the students intrigued, and PC-Solve does not help in this department.

A Note on Block Scheduling

Although not specific to TRAC, some comments on the use of block schedules are in order as they are not a panacea. One loses instructional time with the block schedule for two reasons. First, teenagers don't have a long attention span, and two hours is a bit much to expect; hence if one has an activity that lasts ideally about 90 minutes before students lose interest, then you are saddled with the remaining time that may not be as productive. Second, the actual arranging of the periods results in students being physically in the classroom for a shorter amount of time. (Although home room classes run 55 minutes the other classes last 1.5 hours.)

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

If there had to be a choice between having an activity be high-tech or having it be interactive, it would be more important for it to be high-tech for two reasons:

- The classes which consist of 11^{th} and 12^{th} grade physics students have been exposed to a lot of different activities already. For example, the PC-solve module uses technologies with which the students are already familiar.

- The teacher noted that it is fairly easy for her to take a technology and make it more interactive. On the other hand, for a newer teacher, it might be more of a challenge to enhance the interactive component.

There are several examples of instructional aids that have been used in the past that have worked well. These include:

- *Designing and building* a car that uses only a mousetrap for power. This allowed students to share ideas with one another as they designed their own creations.

- *Going on a fieldtrip* to a theme park, and asking students to take measurements, make observations, and draw conclusions from the physical world. For example, in viewing a roller coaster, why is the first peak the highest, how do kinetic or potential energy change as the car moves forward, and what is the momentum? Students will remember these concepts when applied in the real world.

- *Competitions*. This is something a volunteer could really help with as well: a nearby University's bridge-building contest, another region's contest where students designed exercise equipment for the handicapped, a mousetrap car race (where one student even used compact disks for the wheels) and a "crazy boat" competition where another student went so far as to build a boat out of balsa wood. Not only do these activities cater to students' creative side, but they can also teach fundamental engineering concepts: solving a problem with a given set of cost constraints. This can be tied back to real examples: e.g. Maglev is a great technology but it's also very expensive. One could expand this in the PAC to have a realistic contests (e.g. designing sound barriers for a nearby Interstate) as well as having schools compete against one another, which also tends to engage the students.

There are also activities that have not worked well! Examples include:

- An experiment that gave several different methods of figuring out the relationship between acceleration and gravity. The problem was that most of the methods did not give the correct answer.

- A calculator-based vector lab that had programmed the answers directly into the calculators. Students simply could press a button on their calculator and get the answer. Although this was not stated explicitly in the laboratory procedure, students are not naïve and can figure out this type of scenario.

- An activity that included giving groups of students pans of water. Obviously the designer of that particular experiment had never been around high school students.

- The Milliken experiment via a computer simulation: although the theory makes sense, the outcome is that students simply keep pressing a button until a molecule on the screen comes to a complete stop, which is a rather tedious procedure.

- As a general rule, activities with many individual parts that require a lot of time to set up or activities with many dependent parts such that they must all work in order for the activity to proceed. Although not directly related to TRAC, another example is with the graphing calculator: one can spend an hour trying to download the data and another hour trying to get software to work. Not only do some teachers not like having an experiment fail in front of the class, but they also lose valuable class time.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

There is no SOL test for Physics, which greatly improves the quality of the instruction. There are, however, SOLs for physics. In other classes where SOL tests are used, the teacher is required to cut down on experiments and instead focus on more material that is directly from the textbook. There is also added flexibility because physics is two semesters, so the teacher has time to do both labs and readings. If SOL tests are established for Physics, however, then one should expect PAC usage to decrease as the PAC does not explicitly cover SOLs and labs generally take more time than bookwork.[*] Of course, just because one has taught a concept does not mean students have learned it.

In the future, it would be good to tie in the PAC in with the SOLs. The younger grades (e.g. 8^{th} and 9^{th}) may have some greater flexibility when it comes to meeting the SOLs than the upper grades.

IDEAS FOR FUTURE PAC MODULES

Additional materials, activities, and curricula would be helpful. These include:

- Materials that allow one to make curved track (for the magnetic levitation module).

[*] In short, the SOLs were spawned from good intentions, but they will change the way that science is taught in ways that were never suspected.

- Styrofoam for making Maglev vehicles (same module)

- More than one PC would be ideal. In high schools, fortunately, this is becoming less of an issue as computer equipment becomes readily available. On the other hand, in intermediate schools where there is not as much equipment and the audience is less mature, having multiple PCs that can engage the students becomes a critical need.

- Activities involving a sound barrier would definitely tie in well with Physics. Pollution-oriented topics would be a nice addition as well.

- Competitions, such as those mentioned in the previous section, might even be held on the Internet.

There is one caveat, though:

- The computer lab is not a panacea. Even with a set of networked computers, one must ensure that students and teachers can obtain access with a minimum amount of paperwork. While this is beyond the control of the PAC, designers should realize that not every student will necessarily have a computer with Internet access. It is also possible that with computers used for so many other projects in the school, memory limitations may be a problem.

Note: "The volunteer that is working with me this year is so much help. He is helping us with a bridge-building competition and the kids have already enjoyed having him talk to them about engineering."

Teacher from Virginia School 4

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs.

- A new PAC just arrived this school year; the teacher has used the older PAC for the past 3-4 years and has taught for the past 15 years. She signed up, got approved, and got the equipment, When the computer first arrived, it was quite welcome, since it was the only one she could count on having in the classroom.

- She uses the PAC in both general physics and college preparatory physics where she has a class of 24 students.

- The PAC is used as one of several workstations; in fact, she currently has 4 power Macintosh computers set up as well. This is the second year that she has not used the TRAC IBM computers since the MAC software and graphics are superior. She would be more likely to use the PAC if the software was site licensed or could be installed on multiple PCs or on a network, even if only for two weeks during a year! In short, the ideal would be a computer lab where TRAC could be used by everyone, but for now, TRAC is simply used within an existing lesson plan without specific reference to TRAC as an entity. For example, a lesson on momentum may incorporate the PAC.

- The teacher has not had a volunteer visit but has been assigned a volunteer who has called; logistics have prevented her and the volunteer from setting a good time for a school visit.

- In this class the teacher encourages group work, where everyone has a specific responsibility within their individual team. The ideal group size is a maximum of 4 to 5 people; this way one can divide groups in certain situations (e.g. each half does a lab and compares the data) with 2 to 3 students working together.

- This school is on block scheduling, which means some instructional time has been lost and one is forced to cover material more quickly. On the other hand, block scheduling allows for more classes and more options for students. Generally one has 90 minute class periods.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

As a general rule, the PAC is useful for students in general physics (sometimes called "physics for poets") but is not sufficiently advanced for students in the college preparatory physics. For college prep physics, the teacher will add additional questions or have the students actually perform the analyses. AP physics, which is taught at the school, is a level of difficulty beyond college prep physics. This teacher in particular noted that her years of experience give her a different vantage point than what she had when she first started teaching: she can quickly look at experiments and pull pieces from them that can then be tailored to her own experiments. This is a primary purpose of the PAC.

A lot of this technology and the existing PAC modules might be appropriate for the 8th grade level where students get a half year of chemistry and a half year of physics. In fact, it would be useful to get students familiar with the equipment now, so that when the get to high school they can dispense with the time consuming act of learning how to use, say, the force probes or the motion detector.

Finally, a lot of this technology is duplicated by (or duplicates) material available from other educational material providers. One way to think about these labs is that there are different types of learners: some students are auditory, some are visual, and some are hands-on. Keep in mind that it is this third group to whom the labs should be directed. For the other two groups, the lecture will take care of the auditory learners and the teacher can accomplish the visual demonstrations.

Improvements for the Instructor's Manual

Like the equipment, this teacher views the manual as a potential resource and hence is not extremely critical of it. It certainly may be useful for beginning teachers as well. In the manuals, though, it would be nice if labs were divided into *exploration*, *concept*, and *application* sections.

Motion Fundamentals Module

On the positive side, the teacher pointed out that "this module changed the way I taught graphing" as she used the motion detector to push concepts behind graphing to a higher level. For example, while she would follow the PAC suggestions of getting distance, velocity, and acceleration as a function of time, she would have students then compute the slope of the graph and derive, say, the velocity-time graph from the distance-time graph. She pointed out that on the new Macintosh computers, and the new PAC, distance, acceleration, and velocity against time can all be on the same screen.

This is the best module because it is easy to use and illustrates how to interpret graphs. For example, a teacher can show a graph with a horizontal line and ask what it means. The result will vary depending on whether the vertical axis is distance, velocity, or acceleration. Using this module with motion charades (where the students move around) and driving physics works as well. She also likes that the motion detector is easy to use and doesn't need calibration.

Maglev module

The teacher has never used the Maglev module because she has similar experiments from other educational material providers that accomplish the same type of lesson in less time. "If I could spend a whole week on momentum, then I would probably use Maglev." Multiple sets of Maglev materials also might also make the situation different; when one has one station (e.g. Maglev) that is slower than all the other stations such that it slows down the rotation, then that is a strike against it. Additionally, the Maglev lab takes so long for the students to do (about a half hour) so that quicker labs are more attractive.

In short, the teacher is looking for labs that could be done in 15-30 minutes, and if she had to use a lab that was 50 minutes long, she better have one for every group rather than only a single one in the classroom!

In the same vein, if an air track (or any other piece of equipment) either (1) gives more or better data or (2) is more like equipment that has already been used, then that would be a plus.

Bridge Activity Module

The software is great but a constraint is that there is only one licensed copy; hence this is used as an extra credit bonus where students can come and do the lab after school.

SimCity Module

The teacher used to use SimCity but students weren't interested since many already had the newer version at home. She does plan to use the new version in the future.

PC Solve Module

The general students are intimidated by this module, the graphing calculators have it beat, and it takes students too long to learn. Again, though, keep in mind that this serves as yet another potential resource, as do a host of PAC materials.

Sound Module

The teacher uses this as a station when teaching waves.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

Paul Hewitt's Physics Learning Cycle suggests that a basic lab should have three essential components based on how students learn and process information: *exploration* (where you think about the concept and relate it to phenomena that you can observe), an *activity to develop the concept* (in a momentum lab, one might see objects sometimes bounce off one another yet sometimes stick together, which would be complemented by formulas and vocabulary), and an *application to a new situation.* The C3P (Conceptual Learning and Physics) CD-ROM produced by the University of Dallas suggests these notions for helping people of all ages to overcome "preconceived misconceptions" about the physical world, such as the idea of air resistance.

The teacher had lots of advice on how to encourage use of the PAC in the classroom. Key suggestions are:

- *Use graphing calculators*. For the cost of a PC, one could easily get enough calculators so that students could work in groups of two to four. (While Texas Instruments' calculator came out first, it seems that Casio currently offers a more user-friendly product).

- *Similarly, purchase equipment such that each student (or small groups of students) can do the experiments.* The savings from not buying a PC should also allow one to buy enough force probes, motion detectors, and accelerometers for every student. For use with the graphing calculators, one should check the Vernier Website to download experiments and materials that work with calculators. Schools could then even tailor the PAC to include different "fun things" if tailoring is possible.

- *Involve teachers in this research*. Companies such as Vernier follow this practice; they sometimes will upgrade software in exchange for teacher feedback. In fact, most experienced teachers don't pull a lab directly out of a book but instead extract the portions that they need. This teacher, for example, very rarely uses the labs right out of the notebook but has used the background materials.

- *Relate concepts to what the students already know*. For example, the accelerometer can be tied to centripetal force (e.g. driving around the curve). On a related note, the students enjoy learning about seat belt use with a Barbie™ doll that is first belted and then unbelted. It is also effective to have the students look critically at the world around them: for example, this teacher has a "cartoon physics" blackboard where students identify from cartoons actions that defy Newton's Laws (such as *Wile E. Coyote, Super Genius*) starting his fall after the anvil yet arriving on the ground well before it).

- Based on time constraints, have each student group do a different lab and then *teach their cohorts* what they learned in that lab.

- *Target lab-based classes*. The previous science teacher who was given TRAC did not use it, but he tended to avoid labs in general.

- Use the *PAC Website* so that students can have access to technology, especially applied technology.

- *Shorter labs are preferred* (30 minutes even!) or having more stations of the same lab, so that time can be used more efficiently.

Other types of aids that work well are laser disks, from which, for example, one can have students analyze a video of a collision frame-by-frame since these are indexed fairly well. In practice, Video Discover, Inc. of Seattle Washington (206-285-5400) suggests how to do this with their sports physics program: students can mark the position of a sprinter and distance runner every half second and compare the resultant graphs. One can see how the same concept could be applied to analyze an accident and determine who is at fault. Similarly one could place simulations on a CD-ROM.

What makes a lab fail?

The number one culprit is often the way the lab is written. For example, recall the three basic elements cited previously: a concept, an activity, and an application to a new situation. A poor lab would mix up these concepts; for example, students might be asked to explain why slippery asphalt causes crashes before understanding what exactly is the coefficient of friction. A good lab, on the other hand, would have students understand the concept of friction first; they might compare the textures of wood, sand paper, wet paper, and so, being asked "what is going up? what is going down?" For homework, they would focus on the concept of friction, and then the coefficient of friction, and only later would they tackle the asphalt question. Unfortunately, even college labs fall into the same trap sometimes of being separate from the course. If one returns to Hewitt's argument, one would consider that the labs need to reinforce very directly what is being discussed in the classroom. Jumping from concept to application, on the other hand, is a way to lose two thirds of the students.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

Note that in the AP (advanced placement) physics, comments from the national AP board suggest that teachers have so much material to cover for the AP test that labs, which consume more time than lecture, are discarded. On the other hand, if a class is officially designated as "lab based", then 40% of the time must be spent preparing, conducting, or analyzing the results of experiments. This teacher is a proponent of the second approach.

It would be beneficial if in the PAC lab book one could see how the experiments correlate with SOLs from Virginia and other states, as is currently done with many textbook experiments. It should not be too hard for a teacher to accomplish this as well. (On a side note, SOLs started out very general which was nice, but the fact that teachers and schools are now graded on the results of student scores from standardized tests shifts the focus back to very specific SOLs.) There is currently a requirement that a certain amount of time be spent in physics, even though it's covered by chemistry classes. Since there are time requirements for certain topics, it becomes even more necessary to provide teachers with information on how PAC labs fit in with the SOLs. In the future, it may be necessary to expand curricula in energy, chemistry, and optics in order to meet new SOLs.

For more information on the SOLs, one should look at national standards, such as the recently published Benchmarks in Science Education. Keep in mind, though, that that studies have shown it is tough to concentrate on one thing for more than about 30 minutes. Hence it is *how* you use these materials that is as important as what you use.

Finally, note that from a state perspective AP physics does not have specific labs that must be accomplished; this is different from the cases of biology and AP chemistry.

IDEAS FOR FUTURE PAC MODULES

- *Students are very interested in how cars are engineered*, and there is a lot that could be brought in to the PAC concerning these machines on which they will spend $20,000. For example, the optics within the dashboard design could be a nice complement to the PAC devices that measure sound, as well as design issues concerning the suspension, the motor, and the electrical system. In fact, this is what excites students: being able to apply a concept to a new situation.

- *Use TRAC in other classes* such as biology, where one could look at factors such as alcohol and the nervous system, that affect perception reaction time. In fact, this could be a good *cross curricular activity*: in biology one computes perception reaction time under various scenarios, and then in physics one uses these results to analyze the impact on a collision, especially considering speed limits and distance.

- *Offer multiple levels of difficulty*. TRAC could offer several levels, one for non-math-based physics, one for college prep, and one for advanced physics.

- *Have shorter labs*. The teacher currently uses software that simulates collisions and measures the forces involved, graphed against time. This used with the air track and other demonstrations makes for a good momentum module. Shorter PAC labs, such as this, that cover a concept in different ways would be a more efficient use of class time.

Students from Virginia School 4

During their physics class, discussions were held with the individual teams, where each team generally had between 3 and 5 students. Students were asked about the experiments in physics they liked and disliked, as well as why. Four teams were consulted, and their oral comments as recorded by the interviewer are shown below. Note that students did not necessarily focus on PAC activities; instead they considered the individual experiments they had used in their class, a couple of which are contained within the PAC.

FIRST GROUP

Regarding the lab that uses motion detectors, the number one comment is that the questions are a pain in the neck. They repeat information; for example, the same experiment may require you to compute the slope several times. You're not learning anything new, you're just recomputing the slope! A far better way to write the lab would be to do the following: have the experimenters make predictions and conclusions through a couple of open-ended questions. This way one could spend more time actually doing the experiment and less time writing it.

From an equipment perspective, it was an added layer of complexity of linking the probes to the calculator to the PC. A help sheet would be useful for diagnosing equipment problems.

This group in particular recalled a lab where the questions were duplicative. The original lab, and their replacement questions, are shown in the interview.

SECOND GROUP

A lab that was not as enjoyable due to the sensitivity of the equipment involved dropping a ball; the problem was that it took quite a while to make the ball drop correspond to a particular graph. The concepts behind the experiment made sense, however.

Additionally, with respect to the questions, they do seem duplicative; one finds oneself copying answers from a previous question in order to respond to a later question.

This group in particular rewrote how they would like the ball dropping lab to be done if one could simply drop the ball and interpret the resultant graph, rather than trying to fit the ball drop to a particular graph. The rewritten question is shown in at the end of the interview.

THIRD GROUP

One of the best labs undertaken involved pushing students down the hall on scooters; it was a real application of physics and illustrated concepts behind force and acceleration (especially that a constant force does not affect acceleration). A lab that was tedious involved ticker timer tape; the problem was that one had to hit carbon paper with the pencil in a very particular way or else the data would be meaningless.

The same group noted that the purpose of some of the lab questions is not clear, and that some questions are duplicative. For example, one question might be "Why does the ball slow down" with the answer being "friction." The next question, thought, might be "What impact does friction have on the ball?" in which case the answer is "it slows the ball down."

Finally, better 3D graphics would be appreciated.

FOURTH GROUP

The last group had an interesting disagreement on the use of computer simulations versus experiments that occur in the real world. One member pointed out that computer simulations are excellent because they allow you to spend your time thinking about the concepts rather than trying to make various pieces of equipment function properly. Another member countered that a weakness of computer simulations is that they are not as meaningful as a hands-on application; this individual indicated that he learns more by doing and less by reading.

QUESTIONS REWRITTEN BY GROUPS I AND II

Group I

Situation A

1. Make a prediction

2. Was your prediction correct. If not explain why.

3. Explain the paths of the two rockets and be sure to use data from your TRIAC.

Situation B

1. Experiment with the variables, and record the results and explain why they happened.

Group II

Paula Brizzi
Ball Toss (Kinematics IV)
11-9-98

1. When is the ball at 0 velocity? Where on a graph is this shown?

2. When is the velocity greatest?

3. If you throw the ball up and catch firmly once and catch it lightly another time, how will this effect your graph? Compare the two graphs.

4. If you catch the ball at a higher position than where you released it how does this effect your graph.

Assistant Principal from Virginia School 4

The purpose of the interview with a principal is to identify generally the factors that affect whether or not an educational aid, such as the TRAC PAC, will be used by the school. Hence the principal is able to offer insight from an administrative angle.

FACTORS DETERMINING WHETHER AN EDUCATIONAL ACTIVITY IS TO BE USED

The principal noted that it is impossible to know every piece of equipment that a teacher would want. Instead, he relies on the teachers themselves, speaking through their respective department heads, to indicate what types of educational aids are needed in the classroom. The type of aid can vary greatly: it might be as simple as a ream of paper or it could be a state-of-the-art piece of machinery; it could be a periodic table of the elements or hands-on puzzles that the students use to learn a basic concept. The type of aid is less important. Instead, when considering whether or not an educational aid is to be used, one necessarily asks three questions:

(1) Would the instructional aid be used in the classroom?

(2) Is the instructional aid (to be purchased) something that is not already available through other means?

(3) Is the aid suitable when one considers grade level and curriculum?

Provided that the aid meets the needs of the students by a positive answer to those three questions, then it is likely to be acquired, provided there are sufficient funds within the budget.

Finally, although requests usually come from a specific department, they do not have to. There are examples of cross curricular work, such as physics and technology, English and chemistry, and agriculture and science. In such cases, curricula or activities may be shared among departments.

INSTITUTIONAL CONSIDERATIONS

As long as the educational activity is not offensive, then the questions cited above and budgetary constraints are the primary consideration.

TECHNOLOGY CONSIDERATIONS

This school has three computer labs and is in the process of getting servers which will allow for networked computers as well as Internet access.

MARYLAND SCHOOLS

Teacher from Maryland School 1

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs.

- This physics teacher has worked with the PAC consistently for the past four years and uses it frequently in the classroom. She has primarily 11^{th} and 12^{th} grade students. She also notes that in Maryland, physics is now a required course for graduation.

- For the past four years the teacher has used the same PAC but had just received a new one at the time of the interview.

- The teacher also noted close coordination with the Maryland TRAC volunteer in four ways. *First*, he visits about twice each month to lead the class discussion on various transportation topics; in the future he plans to take the students on a field trip to a construction site. *Second*, he acts as a role model for students to show them that he was just like them and that they can also become an engineer. *Third*, he is frequently contacted by the teacher for technical assistance with some of the experiments; for example, if a motion sensor is going awry, she can call or email him and he will fax a list of troubleshooting tips. *Fourth*, in conjunction with the Maryland State Highway Administration (MdSHA) all of the students are given an opportunity to write an essay on why they would like to participate in the TRAC program to a greater extent. In the summer, between 15 and 20 of these students are selected to work as interns with MdSHA; they also meet with the TRAC volunteer during the planning period in the regular school year. From the previous summer, one intern was so competent in her position that she now works part time with MdSHA during the school year.

- The teacher did note that TRAC tries to solve two competing goals: exposing all students to transportation yet providing those who are interested with a chance to explore transportation in depth. The compromise between these two goals has been to use the PAC in the classroom (exposing all students to it) and also to use it as a springboard for allowing more interested students to show initiative by applying for an internship with MdSHA.

- The school has IBM computers and uses graphing calculators.

- The teacher is involved with a cooperative effort involving the TRAC volunteer and two other schools: distance-based learning. Using closed circuit television cameras, the volunteer will teach a class at the high school where students in all three schools will have a chance to ask questions live; not only will this allow one volunteer to serve three schools simultaneously but it will expose students to this technology.
- The teacher uses team teaching with the PAC, letting other teachers develop activities for the groups of students not using the PAC.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

The biggest problem right now is that there is one computer–and one set of TRAC equipment–for 20 or more students. This absolutely forces the teacher to use TRAC as a "station"; up to five students may work at a time with the PAC while the other students are doing other activities that are part of the regular curriculum. For example, on days when her class has access to the computer lab, the teacher can have some students working on PAC software modules while other students are using other computer software. The 90 minute class periods make it easier to have stations moving between stations. While demonstrations in front of the class are possible, they are not nearly as effective as allowing the students a hands-on experience; hence this teacher points out that to use the single TRAC PAC effectively she must teach such that a few students can work on it at a time.

The teacher also notes that the students are both very computer literate and easily bored by textbook lessons. Hence the more interactive or hands-on that the class can be made, the better. It can be risky sometimes because not every experiment will go as planned, but students do learn by being allowed to make mistakes on the computer and with the equipment.

Finally, except for the social studies module, at least one activity is done from each module. It may not be the case that all activities are accomplished, but the students are exposed to at least one representative activity.

Improvements for the Student's Manual

It would be better to "show more math" that emphasizes problem solving and conceptualizing an equation. For example, students can be stumped by learning how to apply the relationship (F=MA) to real life. In this case, it would be beneficial for the student manual to cover basic questions such as the difference between independent and dependent variables, how to set up and solve a mathematical expression, and key definitions that eventually relate back to the concepts in the module, such as the meaning of elastic and inelastic when describing a crash barrier. Additionally, a layman's index on where to find things out could be useful as well.

More open-ended questions would help students think critically, provide more information concerning what they liked about an activity, and would illustrate how much material they had absorbed. For example, asking students "why aren't Maglev trains used here like they are in Europe" leads to a good question-and-answer process comparing land use and beliefs in Europe to the U.S. Another good example is with the motion module: one may ask "what happens if the car's speed were 60 mph versus 50 mph?" These open-ended questions further make students realize that there is not always a single correct answer.

Improvements for the Instructor's Manual

This teacher noted that she was already familiar with these types of experiments as her college background is in physics, although it is helpful to set up experiments beforehand just to determine where the "kinks" are.

Sound Module and the Motion Fundamentals Module

In both of these modules the key advantage is that students can both (1) do the activity themselves and (2) see the results. For example, they can see the wave describing sound and learn how pitch as heard by the human ear affects the frequency shown on the oscilloscope. Hence it is the act of both making the voice and seeing that change measured in a scientific manner that leaves an impression. The same can be said for understanding velocity and acceleration: students enjoy measuring something themselves, even when it is with a low-tech device such as creating plots via pen and paper (although they do appreciate the automation of the tedious tasks by the computer software!) Students enjoy measuring the speed of cars, for example, and will occasionally come in during their breaks do take additional measurements.

It is also noted that the sensor for the force probe and motion detector is very sensitive and requires some practice before use.

Bridge Activity Module

This hasn't been used yet but from what the teacher has heard it sounds promising.

SimCity Module

SimCity is extremely popular for a couple of reasons. First, it allows the students to *compete*: they work in teams and save their group files to a floppy diskette for future use. Second, they can think of themselves not as students but rather as accountants, engineers, managers, or financial personnel. The end result is that they don't see SimCity as work even though they may be using the same concepts in class.

Since SimCity is a proprietary software package, it cannot be placed on multiple computers at the school even though this computer capability is present via the computer lab.

PC Solve Module

The math skills shown within PC solve are too elementary for these students; many are taking Algebra II/Trigonometry already. More complex mathematics would be appreciated.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

If there had to be a choice between having an activity be high-tech or having it be interactive, it would be more important for the activity to be *interactive*. A simple experiment that works very well, for example, involves light: one can give the students 20 flashlights and have them measure angles of reflection or see how white light is comprised of multiple colors with the help of a prism. *Competition* is also an important element, as noted in the "egg drop" contest where students drop an egg wrapped in a limited amount of materials 18 feet from the classroom window. (In this case the students are given a limited amount of resources with which to construct such a device, such as 50 straws or 50 pieces of paper (but not both) along with one meter of tape.

What works well?

Although not specific to a type of activity, the teacher has an educational philosophy that underlies her use of all activities: in experiments, *never tell students "this is the right answer."* Instead, do everything you can to make them question, retry, and ask, especially because there is no "right answer" in some instances. It is the *process* that is as important as the subject matter: they learn, for example, how to design a car for the Maglev module not by only considering physics principles but instead the various steps in the design process: identify key features (how concave or convex shapes influence aerodynamics), draw up a blueprint, review and check the blueprint, collect materials, and then start building. If students don't get the correct results, the teacher asks the students what they thought went wrong with the experiment.

Inclusion of history helps students place the findings they use in context. She begins with Aristotle and the Greeks in the development of the philosophy of science, and then students are clarified as to the role of Einstein and Newton in determining how gravity works.

One type of activity that has been very successful is a competition where students are required to build "a simple machine." No electronics or robotics are permitted, but students can use pulleys and levers. One student, for example, created a hand mixer; another invented a "scammer" which is a hybrid between a screwdriver and a hammer. The idea here is that students are given an outline and rules, and then they have a design, sales, and construction process for their idea. They are allowed to ask just two questions of the instructor; any more than that and the instructor asks them to again ponder their idea. Once they have a design, they have to "sell" it to the company of which the teacher is the CEO. After this process, they build their design with the help of the blueprint they have created.

Another type of activity that has been successful is the "treasure hunt." In order to learn how to use their graphing calculators, students are told to figure out basic functions, such as the key combination that allows them to store a number in memory.

What doesn't work?

Bookwork or “seat work” does not captivate most students except the more serious. There is a need, though, to be somewhat flexible: a hands-on approach will not get everyone either. Hence one needs to know the modules and what types of students they will attract: for example, the Maglev module works better with some of the more serious students. PC-solve should be avoided for this caliber group of students.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

In general, the PAC is used to reinforce lessons from the physics curriculum. This includes learning how to apply knowledge: students need to be able to think on their feet and consider whether or not the situations being presented are reasonable. Although the SOLs have not been formally published in Maryland, the teacher does have some ideas of where the SOLs are moving for physics and indicates they will cover lots of situational problems: dynamics, kinematics, and problem solving. When presenting this to the class, however, one way to grab students’ attention is to note types of things for which a knowledge of physics is required: flying an airplane, driving a race car, or parachuting.

TRAC has enormous potential, therefore, for reinforcing the physics SOLs in the state of Maryland, and this teacher sees this potential. She notes, however, that for other teachers to see this potential, the teacher must be fairly open minded.

In the Maryland High School Assessments for biology, physics, and chemistry, students have to apply to new situations the knowledge they have gained; they cannot just repeat facts by rote. The PAC is especially good in preparing students for their assessments.

IDEAS FOR FUTURE PAC MODULES

Both specific and general improvements are suggested.

- *More materials* are desired so that one can have a maximum of five students working on a TRAC PAC unit at a time rather than a single unit for the entire class.

- As each student is allotted a graphing calculator, *software that could work with the graphing calculator* would be desirable. For example, the Vernier probes could pass data directly back to the calculator rather than only to the PC.
- A *model of a bridge* that the students could build that would teach them how tension and stress affect structural design and how bridges degrade over time. This could be incorporated with various real-world questions, such as

  --what aspects of the design will need to be improved over time?

  --where would tolls be placed?

  --how and where should the bridge be constructed?

  --on what types of soil will the piles be driven?

  This model should be tied in with what civil engineers do on a day to day basis.

- *3D technology*–not just 2D–would captivate the students. This could be used, for example, to design a bridge.

- A *history module* may be considered in light of what the teacher suggested earlier.

- *Computer programming*, especially with advanced math and physics applications.

- *Videos* that show directly how civil engineering uses physics.

Although not specific to the PAC, the teacher also noted some aspects that would improve the program overall:

(1) Involve college engineering students since they are closer to high school and can give a better perspective.

(2) Have a website that suggests hints for accomplishing the modules, including troubleshooting tips and ideas for making them interactive. This website could also include ways to motivate students.

(3) The Web is not a panacea, though: somehow students need to be kept from going to inappropriate sites.

Finally, the head of the science department noted that other aspects besides physics could be tied into the PAC, such as geology (which would fit nicely with the geotechnical aspects of construction projects).

Students from Maryland School 1

Physics students worked in their lab groups that consisted of between 1 and 4 persons. They were asked to do the following:

(1) describe an experiment they would never want to do again
(2) describe an experiment they would like to do again, or, in lieu of (1) and (2)
(3) create their own ideal experiment.

While these students had heard of the PAC via a school-wide assembly held the previous week, they had not yet done actual PAC modules. Hence they were asked to draw on their experiences from other science courses from intermediate, elementary, or high school.

Names have been included where the students so desired; in fact some insisted that they be given credit for these ideas which are, of course, their own. These responses have not been edited but instead are presented exactly as they are written.

The penny experiment is when you take a real old penny and a new penny and put it under a flame and the old penny turns real dark and the new penny melts because the old penny is made of copper and I fogot what the new penny is made of but it was real thin.

I would like to see metal is melted into metal liquid and back into metal.

1). I'd like to know how electricity and gas equal power and an entire city

2). I wouldn't want to perform an experiment involved unstable radioactive materials.

You could first start at a power plant and from there travel throughout the city. You could even start at one side of the city east or west side and then just stop at the other one.

Don't want to disect:

- Slugs
- Pigs
- Frogs
- Chicken wings

Want to do all chemistry experiments dealings with Elements.

Our group want to experiment:

to build a pollution free car without gas with (solar power, battery power, and steam). with a heavy frame around the car.

1). The best – An experiment that I would like to see done is the one where you have an egg on a pizza tray and underneath of that was a glass you have to pull the pizza tray fast enough for the egg to fall in the glass without breaking.

There was a cup of water with sugar and a cup of water with salt and he had to try both out to see with could make the light bulb come on.

2). An experiment that I would not like to see again is anything having to do with the disection of animals.

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Worse – the worm. because inside the worm looked like it was filled with soil or dirt. The dissecting pins wouldn't stick to the dissecting pan and the worm was very little and fragile. The insides of the worm were very small and unnoticable.

best – the pig. Because how we dissecting the pig by parts. The parts were noticable and it was very interesting even though it smelled funny.

To create and design our own computer and make our own programs. Name it after us and give our problem all types of keyboarding applications, science, history, and math applications.

Create our own experiment of designing a 3 foot rollercoaster it will have a decline from top to bottom an immediate loop followed by a corkscrew and a jump (a marble will be used as a rollercoaster)

Not shown:

> One group did not present a write-up but instead mentioned they would like to build a manned space vehicle. Attempts by the interviewer to steer the group's thinking to an experiment that could be initiated this week (such as a model rocket) were not successful, although one group member did suggest that he would be interested in learning the principles of hovercraft.

Volunteers from the Maryland State Highway Administration

The interviews with facilitators focuses on two areas: (1) whether there are civil engineering or transportation components not covered by the modules and (2) identifying the salient features of the modules that teachers find useful. In this particular case, four lead TRAC Volunteers from the Maryland State Highway Administration were interviewed together, and the attached indicates their collective response.

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the volunteers, understand their role within the TRAC program, and learn their expectations of teachers within the program.

While all four volunteers indicated they are new to the job of managing other volunteers, three of the four do have experience serving in the classroom as a volunteer, with one being in his second year of involvement with the program and two being in their fourth years of involvement with the program. As a general rule, Maryland volunteers aim to visit each school about twice each semester, but some visit as often as once per month. To varying degrees the lead volunteers may find themselves filling in for regular volunteers who are unable to visit a school. Each volunteer is responsible for about 10 schools and supervises between 2 and 4 volunteers.

The range, grade, and subject area of the students vary: two of the four interviewed assist in a technology-oriented classroom, one has a general science class, and one has a physics class. One speaks from the intermediate school perspective; the other three work in the high schools. The students' abilities are diverse as well.

Some teachers are more involved than others, and the volunteers noted that it was quite possible that the interview process could be skewed by the fact that teachers most willing to speak with an interviewer are going to be more active than the average TRAC teacher. They noted that teacher involvement does vary with the TRAC program. Additionally, teachers will call the TRAC headquarters with varying frequencies (some weekly, some never at all), but this is not necessarily an indication of teacher involvement since some teachers may actively use the PAC modules but simply not want assistance. The expectation is that while TRAC may be taught in a 6 hour training course in Maryland (or even in a 3 day West Virginia training course), teachers should be willing to take the additional time necessary to familiarize themselves with the module.

For consideration with other states, note that the teacher assignment process varies: some states may interview teachers to recruit certain types of people to use the PAC (and work closely with the teachers to see where TRAC fits in), whereas in other cases a teacher is simply assigned to the PAC. This may relate to how successful the program is in each school: some schools are understaffed, have large class sizes, and thus not have time to learn the PAC, thereby requiring more volunteer help.

Finally, the volunteers noted that a big part of the TRAC program is the linkage to real-world experience brought by the volunteer. In fact, one volunteer pointed out that tries to achieve two objectives: (1) getting the teacher to use the PAC more and (2) involving the class more with field trips, the volunteer's experiences, and other aspects of the program that stimulate interest in transportation, such as bringing a plan sheet into the classroom.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide. The volunteers in this case noted that some of the questions should really be put to the teachers as well; while the volunteers can speculate based on their observations, they noted that teachers, for example, are the true judge of how well the PAC matches the schools' curricula.

Overall, a lot of the modules are pretty weak, whether it is due to the technology being outdated, the equipment not working properly, or the experiments being poorly planned. For example, the force probes can be overly sensitive (or not giving a correct reading) yet they do not necessarily keep up with computer speeds which are increasing. More often than not, hardware and software does not work, and this affects the teacher's credibility as they need reproducible results.

The volunteers also noted the credibility issue in another vein: students judge them based on the types of experiments and materials contained in the PAC. Hence it is dangerous to use the PC-Solve module, for example, since this tedious software package which uses concepts below the level of most students might be a reflection on the volunteers themselves. This problem is not limited to students: some teachers thought that engineers use these same materials in their daily work. Thus the volunteer must explain both to students and to teachers what it is that an engineer does.

On a general note, one volunteer noted that his biggest difficulty is that he has one PC for 30 students. While in some cases networked PCs in the laboratory are becoming a possibility, it is tough to make a good activity when 30 students must share one set of materials. The ensuing discussion on this point led to another volunteer pointing out that there is variation within schools in terms of what materials they need; a one-size-fits-all solution is not likely to be adequate. (Some schools not only have networks but have their own servers, whereas other schools need more computers overall, and still other schools need more monitors. The PAC seems to be designed for schools without extensive computer capabilities, yet some schools have very sophisticated equipment which does not work well with the PAC.)

The advantage of the PAC is that it allows students to *see things happen*. Whether one is discussing crash cushions (and their relationships to physics) or noise walls, one can associate real-world phenomena to these scientific concepts. Students can "learn by doing."

When asked what makes a module successful, one aspect the volunteers all agreed on was "make it easy to use" which would increase the likelihood that teachers and volunteers could expect an activity to work properly without spending an extensive amount of time in training or preparation prior to the activity.

Introduction to Engineering

This module is left up to the volunteer: some take their classes to construction sites, some explain salary information and what the job is like, and some bring in equipment used by the state highway administration.

Sound Module

As suggested above, volunteers can tie this lesson in with plans of noise walls and concepts such as compression and tension which affect the structure of those noise walls. As a module, though, opinion is divided: some teachers like it and some do not. The equipment works well, but this module is not used very often.

Maglev module

This works great for 8 to 10 year olds, but it is too simplistic for most students. Some teachers can improvise by incorporating other technologies, such as including motion sensors with this activity. Not all of the volunteers have used this particular module in the classroom.

Motion fundamentals

On the plus side, the idea of giving a graph a real world meaning is excellent: students can learn how to associate real-world meaning to this abstract concept. Teachers can accept this, and students like the visual aspect. The equipment and software does not work very well, however.

Bridge Activity Module

This is something where one can bring in a volunteer to explain concepts such as moment of inertia as well as why bridges are built the way that they are.

SimCity Module

Students enjoy SimCity, and it is also used within the social studies program. This also illustrates the volunteer's role as well: explaining to the students how realistic the computed score is as well as how decisions are made in reality. Again, though, a problem is that one wants groups of 4 to 6 on a PC, not 30.

PC Solve Module

This module is embarrassing to the volunteer and is best skipped. Some of the concepts that underlie this module are worthwhile, such as the notion of independent and dependent variables, and lessons such as the yellow light problem are useful as well. Yet this software is simultaneously complex to use and simplistic in its results. Students are used to better graphics from video games, and in fact, *younger* students may be *more* demanding because they are even more familiar with video game technology. It seems that software packages such as Excel could accommodate what this module is doing.

MODULES THAT TEACHERS TEND NOT TO USE

A general comment made by the volunteers drives home the importance of considering the type of class in which the PAC would be used. While one may desire to encourage other teachers to use the PAC, it appears that technology teachers are the only ones likely to use the PAC, and these teachers will tend to use the PAC as a resource outside of TRAC in addition to specific PAC modules. Math and social studies teachers will tend to avoid the PAC as they need equipment that works, and they don't have the time to play with the equipment. However, even general science teachers would like lessons that work every time and follow a cookbook approach.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

About two years ago students competed in a regional TRAC competition with ten activities, mainly based on the PAC. One activity was to construct a bridge with toothpicks and Popsicle sticks. Other types of functions of a state DOT, such as roadway construction, interchange design, and evaluation of accident data or traffic patterns were included as well: the competitions were a big hit overall. There are other useful examples as well: one school is trying to improve the design of the school entrance.

The volunteers all were impressed by a "roadway location" problem that had been presented at the 1998 TRAC Annual Conference by Carlton Flowers of Missouri DOT. The roadway location problem provides each student with a large sheet of paper (about 24" by 36") where teams of two pick the best route for a road that meets certain horizontal curvature standards and destroys the community as little as possible: costs for building the road rise and fall depending on how much of airports, schools, wetlands, parks, and homes are demolished. The volunteers mentioned several characteristics of this example that make it successful:

- *competition* is encouraged
- it is *more than just technology*: students can see how to apply it, and *they make the decisions*.
- it is a *real world example* to which students may relate
- it illustrates there is *more than one good answer* and not necessarily any "right" answers.

- there is *no limit on the number of issues* that may be incorporated [social, planning, engineering, etc.]

One volunteer indicated that it is "a low-tech version of SimCity."; another commented that perhaps the PAC is becoming too technology oriented. This perhaps should be a volunteer-only activity, as it might be difficult to work into the PAC.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

Private schools may have their own standards that they must meet. The volunteers suggested that in order to tie TRAC into the curriculum, they need to focus on solving a problem as well as the nuts and bolts of getting the experiment to work. Again, however, they point out that determining how well TRAC activities fit into the curriculum is a question that should be posed to the teachers rather than the volunteers. (It was also noted that TRAC is cross-curricular and may be hard to place in one discipline.)

IDEAS FOR FUTURE PAC MODULES

Several modifications or additions to the PAC are suggested in terms of content, materials, and emphasis. Overall, the PAC concentrates on physics, whereas in reality the communications and social aspects are important. In fact, one volunteer articulated that "for a transportation program, TRAC does not contain a lot of transportation." Consider inclusion of the following:

- *Equipment used by state DOT personnel*, such as the AASHTO green book, charts reflecting various design standards, the Highway Capacity Manual, scales, triangles, protractors, hard hats, and surveying equipment. Videos, such as a car crashing into a guard rail, can supplement these materials, and a library can be created at the district level. Modules could be created using these tools.

- *Graphing calculators* are becoming common in Maryland and are a likely candidate for inclusion or interface in some form with the PAC, as they can interface with the probes. (The probes and the graphing calculator are connected to a CBL, which thus allows the data captured by the probes to be displayed on the graphing calculator. In this sense the CBL is analogous to the MPLI, except the CBL works with calculators whereas the MPLI works with computers.)

- One volunteer pointed out that these graphing calculators are not a perfect solution, however, as students do not learn how create graphs by hand if the graphing calculator does it for them. Ideally students should still learn how to create a graph on their own when necessary.

- An *environmental* component. Certainly field trips can drive home the importance of biology and ecology related issues, such as cleaning up the Chesapeake bay or understanding the role of stormwater management ponds. A question arises, though: what kinds of environmental lessons or PAC modules could be designed that would supplement the out-of-classroom experiences? One tack would be to focus on related policy questions, such as stream-related problems arising from thermal pollution or the collection of sediment. A demonstration that illustrates how stormwater drainage facilities are designed and what they accomplish would demonstrate problem-solving.

- Lessons that show the *planning, communications, and social aspects of engineering decisions.* "Engineers do a lot more than this!" is how one volunteer described the PAC; lessons that cover, for example, the amount of coordination that must be done with other agencies or restrictions such as being able/unable to put phone lines underground should be included.

- An *economics* component should be incorporated, especially within the bridge builder activities. Over 50 or 100 years, how do different structural designs fare? Similarly [but probably on a shorter time scale] how do economics issues affect geometric design considerations?

- a *design module* (highway, rail, etc.), since this is a big part of engineering and includes, for example, using the correct table with the correct vehicle type, etc.

OTHER POLICY OPTIONS

The volunteers noted several policy options that affect PAC curricula and equipment but which do not fall within a specific PAC module. These include the following

- *TRAC needs a full-time employee at the state level*, not necessarily an engineer, who can coordinate the involvement of the state DOT from a personnel and equipment perspective. An engineer could then assist this employee on an as-needed basis by reviewing proposed lessons and contests for accuracy (e.g. ensuring that students in a design situation are given adequate information).

- *There is a need for PAC that is flexible in terms of available materials*. TRAC is not just a package of equipment, even though a school may have come to expect an updated curriculum: some schools need the PC and some do not. Schools need to be offered a package that they can put on a network, if appropriate, and TRAC needs to get out of the computer business. In short, the PAC would be customized to the school's level of sophistication and needs: schools could purchase six motion detectors, no Maglev, and no PC, for example, or vice-versa!
- The *state DOT can maintain an inventory or library* of materials that could be loaned to schools through TRAC volunteers.

- *Define what is TRAC's mission*. It was surprising that not once did the interviewer ask "what is TRAC's goal in this state" because the perceived mission can affect how the PAC is used. For example, some states want to recruit engineers for the state DOT, some persons want to stimulate interest in transportation from a civil engineering perspective, some persons want to increase student interest generally in math and science; some states want to focus on minority and women recruitment (either in engineering or within a state DOT), and still some persons view transportation as more of an interdisciplinary field to which diverse interests should be attracted.

- *Look more closely at why schools drop out of TRAC.* There has been a tendency for the state highway administrations' TRAC program to grow very fast and then remove schools that don't use the PAC or aren't doing well, but it may be that those schools are the very ones that TRAC should be targeting. One concern is that TRAC programs may focus too much on the "report card" of how a school is doing. While there are a host of policy questions that affect school involvement such as volunteer participation, there are some PAC design elements that may improve school retention, such as

  --*simplicity* (easy-to-use modules will tend to be retained)

  --a *broader range of experiments* that can then be tailored to the level of the school and students

  --multiple experiments that can be done with the same piece of equipment (e.g. get more options with the Vernier software)

  --consideration of the *short attention span* of students and the *size of the classroom* (this may be related to socioeconomic factors)

  --*multiple PAC components* rather than just one uniform PAC. Some teachers are very resourceful for obtaining materials but not all are. With the large class size, consider components that can be fit to groups of four students rather than a single PC for all. Again, a state DOT may have this equipment, allowing one to meet each individual school's needs in terms of curricula and materials. (Some schools can't afford supplemental materials.)

- *Is the PAC a science lab, demonstration kit, or something else?* Right now the PAC seems to achieve two objectives: serving as a source of classroom demonstrations done by the teacher yet also serving as a set of experiments that may be done by groups of individual experiments. It does not do either very well. In the future, should the PAC be viewed as a single demonstration in front of students or sets of individual hands-on activities? Being in the middle is not a solution. (For example, the current PAC can only entertain ten students maximum at a time. Rotation of groups is an option that is difficult to do on one-hour days, and even with smaller groups each person needs something to do.)
- *What is the next level activity?* When students do an activity, they then cannot take it to a more advanced stage in following years. TRAC activities need a level of progression, so that students who are exposed to the PAC in one grade can use it again in following grades with more sophistication.

- *Increase coordination between activities*. Right now, experiments such as the bridge builder and noise walls are very fragmented; there needs to be a unifying theme.

Teacher from Maryland School 2

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs. This particular interview was done by walking around with a clipboard and talking to the teacher as she prepared for her class.

- She noted that she has been with the TRAC program since last year. Apparently, though, the PAC has been with the school for three years before she came, and it was an additional two years before she realized the PAC was available. The science teacher, who had had the PAC during that time, couldn't work the PAC into the curriculum.
- Her students are all in the technology program.
- The new PAC was just acquired a month prior to the interview.
- She noted strong coordination with the Maryland program in terms of obtaining what she needs, as well as the fact that she had been through the full two-day TRAC training provided by Maryland. She pointed out, however, that while engineers may supplement the curriculum they should not, in her view, be responsible for teaching the class.
- Her students have demonstrated a strong ability to compete successfully against other schools in the scientific arena; for example, the previous Sunday students had participated in a "physics contest" and had come in 4^{th} out of over 30 schools. The contest has multiple components, such as a pumpkin drop, where students use basic materials (straw, paper, etc.) to build a container to ensure that a pumpkin can survive a drop of over 100 feet.
- The classroom was unique in that there was a lot of equipment already set up for different types of experiments. The PAC, therefore, is used as one of several workstations: a couple of students might work with the PAC while other groups of 2 to 4 students might work on other workstations, that focus on different technology areas, such as automobile manufacturing or wastewater treatment.
- Associated with the bullet above is the fact that this school works with other providers of educational materials, such as Johns Hopkins University (which has installed two computer labs) and private corporations (such as Applied Educational Systems and Hearlighy & Company). For example, in this classroom are 12 PCs, although each has less than 1 Megabyte of memory due to funding constraints.
- The teacher noted on several occasions **the importance of understanding the diverse range of student abilities that will be present in the classroom**; not only might students with different official grade levels (9^{th} – 12^{th}) be together, but students' abilities will vary as well. For example, in the classroom there might be students at the 6^{th} grade reading level and at the 12^{th} grade reading level sitting next to one another.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

The teacher emphasized the importance of coordination with the TRAC volunteers as opposed to specific TRAC modules. For example, she would try to get the students to answer "Why do you even need to learn math or science?" Transportation related topics may bring this in, such as how fast cars drive and how this causes accidents.

In general, some aspects that do not work or are troublesome include:

- having technology that is outdated compared with what is found within a state DOT (such as monochrome monitors)

- requiring students to make assumptions in order to move between the various steps in an experiment. Some students are not able to do that.

- not having enough lab space for activities such as vehicle acceleration and Maglev. The teacher points out that this is not the fault of the TRAC PAC but instead is a function of the classroom setup; however, it is a factor of which activity designers should be aware.

- it's hard to get a group of 30 students around one computer.

Improvements for the Student's Manual

On the plus side, students like and need the step-by-step process reflected in some of the activities. On the minus side, it can be tough if one does not have success at a certain point (e.g. if the equipment fails and thus one does not get the results one should get. For an activity to be successful, designers should understand the level of frustration of the students.

Students will tend not to read the manual; hence they would benefit from help menus that specify which actions a student should do first (e.g. before doing x, you must do y).

Again, the diverse range of student abilities must be considered: if you give students instructions to an experiment, note that some will understand it perfectly, some will be able to read it but not understand how then to proceed, and some will not even be able to read it.

Finally, keep the questions in the manual but add more details regarding how to conduct the experiments, so that it will be easier for students to follow. Break the labs down into smaller steps. Slow the activity down. Also, make the steps in the software more explicit before trying it with the students.

Improvements for the Instructor's Manual

Ideally the teacher would like to have two weeks to learn all the details of the modules, but with the teaching schedule there is no chance to prepare for lessons except during a planning period and on her own time. The three days of training offered by TRAC in Pennsylvania are not enough, as the training was rushed. If students have 20 days to prepare and do an experiment, the teacher should have at least 10 days to prepare herself! In short, teachers never get enough time for preparation.

The *Motion Detector and Vehicle acceleration* module was not enjoyed by the students because they all couldn't work with the computer. On the other hand, they can actually see the relationship described in Newton's law as well as the everyday applications. This requires considerable space, and that is sometimes limited.

The teacher noted the success of a bridge builder module where students make a bridge out of balsa wood designed to hold 125 pounds, and then place successively heavier loads on it until it breaks. This is something that, although not part of the PAC, can be done in conjunction with the PAC *bridge builder software* (and another bridge builder package, CPAC, that has audio capabilities). The students like to manipulate the input parameters in the software, though, and see how these are affected. The teacher supplies the materials for bridge building, and the students really enjoy succeeding at creating a bridge that can withstand the 125 pounds.

SimCity's graphics are great, but some changes to the software, such as the fact that houses now require power lines and telephones prior to their construction, can be frustrating to students. Overall, though, students really like this module, especially the new audio.

About two years ago students won a competition with the *Maglev* module; when there was adequate lab space last year, this module was used successfully. Now there's not sufficient space in the lab to do this activity.

The utility of *PC-Solve* really depends on the student. For some, the plots are useful; but for other students, seeing the following fraction

$$\frac{3}{4}$$

when written on the board, means nothing. Hence, a question about "how useful is PC-Solve" is inappropriate; instead, one should focus on using the TRAC PAC's flexibility to target different types of students. The way it is written is perfect because it allows for flexibility.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

What works well?

Again, this classroom is of interest because the TRAC PAC is set up as one of many stations, including residential building, bridge building, and automobile transportation. As a general rule, though, one thing that works is to have a 15 minute discussion prior to beginning the lab, where the teacher tries to make the lesson personal to each student. Based on the students' discussion, the teacher can then tailor the lesson to the class. This also allows the students to see the purpose of the activity that they are about to undertake. Since time is limited, labs that don't require a lot of background are excellent, as well as labs that allow students to focus on solving a problem. Graphics are very helpful as well!

The part of TRAC that appeals to students and "gets them geared up" is the hands-on aspect where they get to produce and apply principles. It makes science fun. TRAC also builds in little "successes" along the way as students perform the experiments. The students react well to the step-by-step instructions.

Finally, the PAC activities also allow for differences in the academic level and preparedness of the students. Some students are so gifted that they react well to independent learning. Others need careful instruction.

What doesn't work?

An example of a non-PAC instructional aid that is not used much is an "environmental management" activity. The idea behind the aid is good, but the technology itself is boring: the visuals are weak and students simply spent ten days using colored pencils to describe water usage. Instead, a good activity should have engaging, interactive software and it should provide the students with the chance to affect the outcome of the activity.

In the past, TRAC was held, but not used, by a science teacher. When asked what keeps a teacher from using TRAC, several suggestions were offered:

- *no clear relationship between the activity and the curriculum*; e.g., how do you tie the PAC into a lesson for health or biology? Similarly, one needs a concrete lesson plan that ties in the PAC activity.

- *large class size*; at a minimum, one needs to be able to give more than one minute of individual attention per student, hence a class of over about 35 renders the PAC more difficult. Small classes are better for the PAC.

- *administrative hurdles to obtaining equipment.* An example was given as to a suburban middle school that received a $25,000 laser for a class size of 19-20 students, yet this teacher has trouble simply obtaining supplemental materials for the PAC for her students. This is very frustrating.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

Within the technology curriculum there are five skills for success: thinking, learning, technology, interpersonal skills (e.g. communication) and math/science applications. You can incorporate all of the skills for success in any of the PAC modules because they all involve problem solving; the teacher can bring students back to the goals of the lesson and the curriculum.

IDEAS FOR FUTURE PAC MODULES

Currently TRAC focuses on math, civil engineering, and social studies, but it could also concentrate on other subjects as well, in addition to expanding within these traditional areas. Examples include:

- *using investigative reports* (e.g. assuming the role of detective) to learn about other subjects. For example, via the Internet each student can pick a state DOT, learn how it is organized, and what are its highway standards.
- a module on *satellites* in space and their role in transportation, technology, and communications.
- a module covering *waste management*
- use the *ambulance* from SimCity in a *health class*.
- Put SimCity and the Maglev modules on all the school’s computers.

Students from Maryland School 2

Students worked in their lab groups that consisted of between 2 and 4 persons. They were asked to do the following:

(1) describe an experiment they would never want to do again, or

(2) describe an experiment they would like to do again, or,

(3) create their own ideal experiment.

Students were asked to describe the experiment, what it would teach them, the materials necessary, why it was good or bad, and any "tricks" that future experimenters needed to know in order to do the experiment correctly.

Not all responses are shown, but the ones that appear below have not been edited but instead are presented exactly as they are written.

The experiment I want to do is build a bridge. It is good because I want to build a bridge of my own. I also want to build one of my own because I had never been assigned to build a bridge of my own. The materials I will use will be wood, crazy glue, and a razar blade. It will teach me how to build a bridge of my own.

Hello my name is *** and I worked with waste water management and I didn't like working at that station because, it was very boring and I don't think that anyone should have to suffer that boring work. I really like building things and constructing things for someone who likes to sit down and add things into water and take things out of water would probally like that. That's why I'm now at the residential construction station, where you build houses (means building a house with sticks and glue).

I think that another station that we could add is to learn how to build rockets scence. Out teacher Miss ball use to do that before she came here to teach. I think that would be very interesting.

My Experiment

I would like to see a cure for one of the most deadly man made disease Aids/Bono virus. I believe that it can be done. Because doctor's, lab scientists have the technology and equipment to perform this, but us as a people have seen no break throughs to ending these diseases.

Ways to go about doing it: geather a team of specialist from all over the U.S. and put them all together. A dream team it you may to accomplish this difficult but very much needed task!

If interested and you are not in a doctor's position at the present you can help by finding out as much as you can about the disease doing your own personal research and getting involved because if you are not appart of the solution your appart of the problem.

The experiment I disliked the most was building the spaghetti bridge. This bridge was sort of complicated because of the hot glue gun and knowing you have to put at least 50 lbs. Of steel bars on it. This is an experiment I wouldn't like to do again.

An experiment I would like to do is build a city of the future.

At automobile manufacturing I had to make a car that look like robot. The things we had to do is take a board and put red and black tape on the board. The robot had to be program from a computer. I had too program the robot to follow the red and black tape.

The name of my project was the pumping station. It show you how the oil (water) stop pumping at seapoint and when it drop down seapoint it start to pump up again. I would like to work on it again it is fun when you read the directions.

My experiment was to make a bridge out of pasta noodles to hold steel bar. My experiment work out good. Because I had the maximum weight in the class. The stuff we need to make the bridge was glue, glue stick, pasta noodles, steel bars. The trick I did to make my hold so much weight was to it flat and glue the whole bottom of the bridge. The minimum weight was 50 lbs. I had 62 lbs. but on my bridge.

One experiment I worked on was building a house. I enjoyed building my house. It was good because it give me a chance to see house engineers do there job. Materials that I used where wood strips and glue from a glue gun. This is a little model of my house.

The Windmill

The experiment that I did was build an windmill. It was a good thing to do so al could see how the windmill is to be made and how it works. In order to make the windmill we had to use 4 sheets of paper, 4 sticks, glue, and a generator. When the windmill is put together in order for it to move you must make sure the blades are in a certain angle faced the same way and then cut a fan on a coupl inches away from it. The experiment taught me how windmills work without any electricity.

I enjoyed making a windmill because it was a easy but very important project. I would recomend people to try this experiment. All you need is 4 peices of paper, 4 sticks, and a generator to make the windmill. To build it all you have to do is glue the wood to the paper. Then you attach it to the connector peice and put on the wind operated generator. To make it work you need to use a fan.

Teacher and Volunteer from Maryland School 3

Note that these results are a synthesis of comments made by the volunteer and teacher along with notes that they graciously provided! Note also that the volunteer is employed by the Federal Highway Administration.

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs.

- This school caters specifically to high school students who have had problems with substance abuse. It is unique in its size; 30 students total, 16 per class, and in the particular class that was observed, 9 students were present. It is also challenging in that there is high student turnover; the students had been on a field trip earlier during the year to observe the construction of a noise barrier, and only three students who had been on that field trip were present the day of the interview.

- The teacher has been using the PAC for the past five years, although this is his first year with the new PAC. As of yet, the computer associated with the PAC is not working, so the teacher has not been able to do many of the modules this year.

- Realistically, the volunteer must prepare for the lessons on her own time, and she aims to meet with the class about once a month, focusing heavily on activities that (a) look interesting and (b) relate to the volunteer's work. The teacher may also use the PAC for other activities when the volunteer is not present. The volunteer concentrates on what she knows and how activities relate to her job and the real world.

- The teacher uses the PAC primarily in the technology class: he is a math teacher and was the one faculty member who was willing to take on teaching technology when it became a required course.

- Although technology students were visited, note that the instructor also uses the PAC in a math class, where students use the probes to collect and analyze real data (rather than random numbers out of a textbook). Group work with graphing calculators is done with math class as well.

- The training instructors had not used the PAC very much. When the teacher originally got involved with TRAC, Tate Jackson [a representative from TRAC National Headquarters] had visited him on site. The teacher thus had an entire day to become oriented, and this worked very well.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

Improvements to the Manual

The manuals need four main improvements. *First*, include some discussion on what the point of each activity is. Right now, if one wants to do activities relating to crash cushioning, for example, one probably needs either a strong (and recent!) physics background or one needs to read a few pages from a physics text explaining what the experiment means. *Second*, include the answers to questions. This would especially be helpful for teachers who are in a new program area. *Third*, tie the activities into transportation: explicitly state, for example, how velocity and acceleration are used in civil engineering or how SimCity relates to urban planning. *Fourth*, state which materials each activity requires; for example, one can do (as was done the day of the interview) the sound module without a PC, but a first-time reader might not realize this.

Improvements to the Modules

The teacher and volunteer have used in the past the *sound* module (loudness and noise pollution, designing noise barriers) the *motion fundamentals* module (cushioning collisions) and the *math modeling module* (distance and velocity match). The volunteer has also led the overview module of "transportation and engineering".

- According to the teacher, *Bridge Builder* is one package that a student recalled using, but the instructions on the software are not clear. Yet the student had an interest in the topic of bridges. Instead of the software, it was noted that both a slideshow from the Federal Highway Administration (FHWA), as well as having the students build bridges out of balsa wood to learn about stress and strain, were useful activities. If the software is to be used, it would be better to have lots of computers with Bridge Builder, since there are at least two PCs per classroom.

- The *motion fundamentals* module can be used to illustrate algebra concepts and line slopes. Toy cars and foam may be used to relate this topic to transportation. Unfortunately, the probes pick up extraneous data which makes it hard to explain the concept to the students.

- *Maglev* is flexible in terms of the level of student who could benefit, however, most engineers would have to "bone up" on Maglev before the class, since this is something they do not use.

- *SimCity* is not used by the volunteer as she does not have it at home or at work. (It is also something the students can use when she is not present.) The volunteer also spends her own time at home preparing the lessons and practicing with the equipment, yet this is not possible with SimCity unless the volunteer drives to the school at a time when the PAC is not being used. As a general rule, the volunteer does not have available her own PAC and must rely on training she received initially along with her work experience to devise activities. The teacher noted that SimCity is tricky in terms of trying to get the highest approval rating, although it is nice that it is self-contained, but needs to be available to more students simultaneously.

- The crash cushion activity [*force probe*] would benefit from three or four more cars so more students could participate.

- The *sound module* was used by the volunteer on the day of the interview: the class took readings off of the decibel meter which was facing a clock radio. The readings varied depending on what type of barrier was between the meter and radio and the distance between the meter and radio. (As an observer, the lab is a good reminder of how variant "real-world" data can be; for example, sometimes the noise level would change because the song or static from the radio was changing or even because of a student humming quietly along with the radio.)

- *PC-Solve*'s queue problem has been used in math classes. Note, though, that students need to receive background on traffic congestion before attempting this problem so they can relate it to the real world.

Although the computer was not working and could not have been used anyhow, the volunteer noted that even if it had been available, there were a couple of disadvantages of the PC. First, the software does not show a direct graph of the decibel readings but instead shows a [fast-Fourier transformation] FFT graph, which adds a layer of confusion. (Recall that one must spend some time simply explaining why "80 decibels" is actually ten times louder than a reading of "70 decibels"). Second, the computer slows down the lab a bit; without it, the volunteer was able to conduct the experiment and relate it to sound barrier construction within the state highway administration all in about 45 minutes. (The teacher did note, though, that the computer is attractive to the students.)

Finally, the teacher and volunteer noted that plotting x and y points by hand on a graph is something that will bore the students; it is far more interesting for them to take measurements.

Several improvements should be considered for the PAC:

- Obtain a site license for these various software packages, so that they can be deployed on multiple PCs.

- The activities need to be hands-on and involve <u>all</u> students.

- The modules need to be geared towards the right age level: high school students, for example, probably won't know about the different types of distributions (e.g. Poisson) in the queues activity.

- The activities should focus on problem solving.

- The use of guest speakers to follow up on students' questions should be encouraged. The volunteer invited an expert to speak on underwater construction of tunnels after students had asked how this was done.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

Hands-on activities are crucial; if one is going to use a PC in a class of 16 students then probably two other activities should be going on. If students are not directly involved, then their attention starts to wander. One excellent low-tech activity that students are doing over time is building a chair, solely with 20 feet of masking tape and refrigerator boxes, that can hold the instructor. Regarding the PC, the instructor noted "It's a disadvantage to have this wonderful tool and not be able to use it with the whole class." The students also responded to problem-solving questions, such as "how are we going to push something this far" or "how are we going to cut off this sound?"

The teacher and volunteer noted that short videos or slide presentations (e.g. 15 minutes) are helpful for engaging the students. Other topics such as a history of bridges in Maryland (the presentation used high quality colorful slides and led to a discussion of bridge stresses), construction projects such as roundabouts, tunnels, and major bridge rehabilitation, and traffic calming techniques are useful. Additionally field trips work well; the recent trip to view sound barrier construction prompted some questions that came up during the volunteer's presentation. As part of a forces of flight activity, the students also got to ride in an airplane flown by a TRAC trainer, which needless to say is pretty exciting and can drive home the applicability of certain motion concepts. (This concept was later used during boomerang construction.)

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

The SOLs are not as integral a part in this technology class as they would be in algebra and geometry. As explained in the one page overview of Maryland's "Exploring Technological Concepts" there are four broad categories of student outcomes: "mechanical systems", "harnessing natural resources", "energy on the move: waves and impulses", and "innoventions." (not a typo). Within these categories are several specific outcomes that relate to PAC activities: problem solving, group activities, and the construction of models and devices.

IDEAS FOR FUTURE PAC MODULES

In general, the PAC modules should be oriented toward doing projects that solve problems, especially transportation, rather than simply serving as a set of physics experiments. For example, in a state highway administration, engineers do a lot of work in the areas of planning, design, construction, and maintenance; PAC activities should cover these areas. Additionally, several PAC modules should cover the following:

- Especially on the TRAC website, cover *salaries for engineers and college entrance requirements.* Since students always want to know salary information, this question could be addressed once and for all by TRAC; then, interested students could be told what education they need to get that salary.

- *Title each activity as a civil engineering concept* (e.g. structural design, safety, noise abatement, or "traffic congestion!") rather than simply as a science lesson (e.g. "queues" or "motion fundamentals". This will make the module seem more interesting and also will allow one to see the direct link to civil engineering. It also makes it easier for the volunteers to see how the module fits into their jobs.

- *Add activities done by a state DOT*, including bridge design, park and ride lot design, environmental modules (including noise barriers), soils (and their impact on various types of structures), safety, and hydraulics. The bridge design, environmental design, and other major offices in State DOTs should be surveyed to select topics.

- Give an idea as to what types of *field trips will support the PAC activities*. For example, it may not be feasible to have a PAC activity that illustrates a hydraulic jump, but a visit to a nearby University's hydraulics lab could accomplish this just as well or better! Hence in the PAC, give some detailed guidance on what types of field trips should be encouraged.

- Include *videos of car crashes or crash tests*: students like to talk about engineering design failures and or catastrophes, and this interest can be tied back to some fundamental transportation concepts. Other aspects of civil engineering and transportation, such as how demolitions are conducted, could be covered. A video of a bridge demolition also caught the student's interest.

- *Help students relate to PAC activities prior to beginning the activity*. The Maryland slides shown on the history of bridges were a good precursor to building balsa wood bridges, because the students could relate to the different types. Videos of the Coleman and Wilson Bridges were helpful in this arena. As another example, the volunteer had shown videos of car crash tests prior to the activity of constructing crash cushions.

- Use graphing calculators, CBLs, or a computer projector so that *all students* can see (or preferably do) the graphing activities.

Students from Maryland School 3

After seeing a TRAC sound module, the technology students were asked what types of activities they had done that they found boring or interesting. Their responses, some oral and some written, are provided below. In retrospect, it became clear that with this particular group the interviewer did not do a very good job of eliciting views from the students; if the interview were to be done over, it might have gone much better to simply restrict the questions to what the students had observed that particular day. Comments from the teacher and volunteer, however, helped clarify some of the students' answers.

Boring Math, Science, or Social Studies Experiments

- Watching a seed grow: nothing happened for several weeks!
- Geometry problems are hard and take a long time to relate to.
- Listening to a lecture about Congress and the Senate.

Interesting Math, Science, or Social Studies Experiments

- Discussion of war stories is interesting (Vietnam War, Civil War), with them being action oriented. (Note that later the teacher noted that one could conceivably relate this to explosions, which does interest students, and the science underlying them).
- Use things that people can relate to, such as music! One time the teacher made up a song to get the point across!

Written Responses

"I liked a project that I did in 5th grade. It was a machine that showed you what smoking did to your lungs. The worst one is the one were doing now in tech were building now. It's a cardboardchair. It would be better if I acually worked on it."

One project that I liked was in photography and my theme was to show the ugly pace of beauty and this was done in black and white and I decided to _______ god and its _________.

To interest people we have to show the horrid potrid side of things like in deseases the nasty sores the pain and uglyness that comes from that and that's what might make people think. Or also attract the because our dark side is attracted to that.

Plant a seed and wach it growe. I think it needed more sun light. Waching war movies or talking about war stuff.

Stupid. Building a chiar my chiar always falls apart.
Cool. I don't have one.

Stupid. Playing w/nasty clams and stupid field trips. Cool. Watching movies abut people doing experiments. Because I do. Not all most people would rather watch someone do something then ourselves.

I liked labs on DNA in biology. We did a lab so we could see the structure of a DNA strand. DNA samples - we took DNA from an oyster and put it under a microscope.

Stupid. You had a breath through a straw.

Best experiment: Disecting grasshopper digusing because I don't think I needed to know what the inside of what a bug looks like. Worst experiment: See if what would happen if we put wet bread in the sun and in a closet.

When I use to talk to my teacher about boot camping at Paridise Island and how horrible it was.

Later Interview with One Student from Maryland School 3

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

The student's class at Phoenix II did the Sound activity about 3 weeks ago. This is the only TRAC module that the student remembered. (He had not been on any of the field trips.) The class members spoke into a microphone (referred to as a "black thing") and then played music, and noted the corresponding wave forms on the computer. One lab activity was to differentiate between higher or lower tones based on the wave form.

The student liked this lab activity, except that (1) it was kind of slow due to computer problems, and (2) it was hard to get started and their teacher had to come and explain how to get into and use the program. He noted that the lab was "pretty fun" and that he had learned a lot, specifically how noise is transformed in the ear and what makes tones high pitch and low pitch. On a scale of 1 to 5 where 5 was "great" and 1 was "boring," the Sound Module scored a 3.

OTHER INSTRUCTIONAL AIDS/ACTIVITIES THAT HAVE BEEN USED

When asked to describe some science activities that scored a 4 or higher on the previous scale, the student mentioned the "chair project," in which students built a chair out of cardboard that was strong enough to support their 200 lb. Teacher. He liked this activity because it was "hands on" and required actually building something rather than just working with the computer. He also listed building a CO_2 car and building a bridge out of toothpicks and glue. He especially liked the bridge building project because students competed to see how much weight their bridges could hold. Winning the bridge contest gave him a feeling of having accomplished something, and he liked competition in general, but when asked if the other students liked contests, he said that they didn't, perhaps because they don't win. He indicated that prizes or incentives might encourage the other students, and that being told that as long as they did their best, it didn't matter that they didn't win might also help. When asked what characterized labs that scored a 1 ("boring"), he mentioned activities that were really complicated, and involved pencil and paper or bookwork only.

Principal from Maryland School 3

FACTORS DETERMINING WHETHER AN EDUCATIONAL ACTIVITY IS TO BE USED

One of the major considerations in the principal's acceptance of new programs or curricula in her school is whether they address technologies necessary for student success and whether they result in improvements in the students' technological "comfort levels**."** Although their technological needs aren't limited to computers, her students' primary need is to become comfortable with computer technology, and programs that both help pupils enjoy using computers and maintain a high level of interest and involvement have an advantage over those that don't.

From a practical point of view, several factors can eliminate programs from consideration. *First*, as in many other schools, *many programs are too expensive. Second*, since the schools may have limited manpower and expertise in certain areas, a *considerable amount of support is needed* to establish the program. Many curricula sold by private concerns offer little after-the-sale support, either in demonstration of the program and its activities, training, or technical assistance. For the TRAC program, training is available, volunteer engineers help with both setting up the program and in tying it to the real world, and technical support is available over the phone. Not all programs offer such extensive support. *Third***,** many *schools are not physically set* up to successfully implement programs. Sometimes programs are incompatible with existing school equipment, particularly computer equipment, or require a computer network (or conversely, offer only single copy software rather than a site license). *Fourth*, many programs *are not well designed* and do not include components that teachers need to make the program successful. For instance, some programs assume that the learner has advanced to a certain academic level, but do not include assessment tools to make sure that students being considered for the program have achieved this level. Other programs *do not provide a mechanism for obtaining learner feedback. Fifth*, some programs can be taught by an individual teacher, while others require additional teachers or teaching assistants, and still others require a *student-teacher ratio* that their school cannot achieve. *Finally*, some programs require a higher degree of learner independence than this principal's students have.

INSTITUTIONAL CONSIDERATIONS

According to the principal, administrators in Montgomery County need to make sure that their schools' infrastructure can support new programs, particularly considering questions such as whether the schools' hardware and software are compatible with the program requirements and whether they have the physical space necessary to teach the curricula. In this particular school, classrooms were designed for a small number of students, making the setup of laboratory experiments difficult. Students not only need room to work with the equipment, but also room to move around without disturbing the setup.

As another example, the principal had to fight very hard just to get two Internet connections per classroom. Since the school is so small (about 30 students) it is impossible to get a full scale "computer lab" which is feasible in some of the larger high schools.

Former Maryland TRAC Student

This student became familiar with TRAC during her junior year in high school, when the PAC was used in a course. She subsequently interned at the Maryland State Highway Administration (MdSHA) during two summers before attending Duke University where she is currently enrolled. This person was able to offer a unique perspective on the TRAC program and the TRAC PAC toolkit as a former student.

The authors initially felt that interviews with former students who have been the "TRAC success stories" would provide a somewhat stilted picture of the program and its influence. However, this student's interview seemed more balanced than expected and included both positive and negative comments.

HOW WAS THE TRAC PAC USED IN THE CLASSROOM?

The teacher presented the PAC to the engineering students as one of several options for conducting a third quarter class project. (Other options included robotics, for example). In this case, the student chose three out of ten problems, specifically intersection design, Maglev, and being a district representative. In the ensuing statewide competition, she placed second overall.

Although MdSHA has been upgrading their TRAC program since that time (there are now TRAC stations in the classroom), at that time the project was largely student-run: the teacher basically said "Here are the materials: go to it!" The teacher simply did not have training or familiarity with the PAC or civil engineering to help with troubleshooting when equipment did not work well, and this was very frustrating since the manual was not helpful either.

On the positive side, however, the TRAC volunteer did visit the school, and when he came to visit the students asked lots of questions, especially because they and the teacher had no prior exposure to the material. In this vein, the cooperation between students, teachers, and engineers was very helpful; and in retrospect, the student noted that at TRAC training the message was that students may need to be led through the activities step-by-step.

OTHER INVOLVEMENT WITH TRAC

Her success with the PAC led the student to apply for and win a position at MdSHA where she worked in the hydraulics section and used CADD software (e.g. MicroStation). During that time she was able to attend TRAC PAC training sessions regarding the modules on Bridge Builder, SimCity, and the motion sensors. Overall, she was pursuing actual engineering work, doing design and the like, rather than simply making photocopies.

ADVICE FOR SPECIFIC TRAC PAC MODULES

Overall, the student felt that a computer upgrade was needed [although she noted that this may have been done by now].

Teachers should be familiar with the equipment, which she now believes is the case.

Policy debates may be incorporated into the social studies program, such as ethical discussions regarding the use of wetlands. (She was unaware of the TRAC social studies module). In fact, teachers need to become familiar with these types of topics: there are a lot of people who really don't know what engineers do.

IMPACT OF THE TRAC PROGRAM ON THIS PARTICULAR STUDENT

The student noted that her job with MdSHA which she won as a result of TRAC involvement, was key in her decision to select a career in civil engineering. She stated that "He [TRAC Volunteer Steve Kolk, who also was her supervisor during the internship] is one of the biggest role models in my life." This internship itself, as well as the interaction with the volunteer, was far more important than the actual PAC activities that were undertaken.

Additionally, the timing of the program was critical: it occurred at the right time (Junior year) just as the student was considering careers in medicine and engineering.

HOW DID TRAC AFFECT THE OTHER STUDENTS IN THE CLASS?

When asked if other students had experiences with TRAC that were less satisfying than hers, the student mentioned a friend who had gotten very little out of the program. She also mentioned that this friend had not had the opportunity that she had had to work at MdSHA, which was the key influence in her career decision.

Former Maryland TRAC Student

This former student became familiar with TRAC during his senior year in high school in 1995, when he used the oscilloscope as part of a senior project at Baltimore Polytechnic High School. He subsequently interned at the Maryland State Highway Administration (MdSHA) during two summers and will be graduating from Virginia Union University this year with a major in math and a minor in physics and computer science. Although it has been four years since he used the PAC, he was able to a valuable perspective on the TRAC program and the TRAC PAC toolkit as a former student.

HOW WAS THE TRAC PAC USED IN THE CLASSROOM?

In this case the student used one part of the TRAC PAC - the Sound module, which includes the oscilloscope and the noise detector - to perform his senior project. Over a two month period, he gathered statistics indicating how well noise walls maintained by MdSHA perform. In the classroom, he then built and tested a noise wall out of rubber tire, which is a different material than that which is used by MdSHA. He found that the rubber tire-based noise walls did a better job of containing the sound. His project culminated in a presentation to MdSHA and U.S. Department of Transportation officials, including Federal Highway Administrator Rodney Slater.

Although most other students in the class did their projects in groups, he worked on this one individually. He also noted that the TRAC PAC was used with the class in a few other ways as well, such as measuring vehicle speed with the motion detectors.

OTHER INVOLVEMENT WITH TRAC

As a result of his project, the student interned for two summers with MdSHA. The first summer he helped promote TRAC throughout the Administration, and he became familiar with some of the other modules, such as SimCity and the use of the motion detectors for testing physics concepts. He was also a TRAC intern the second summer, but this second time he participated in a rotation program at MdSHA, where he worked with different departments, such as signs and safety.

ADVICE FOR SPECIFIC TRAC PAC MODULES

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

The student noted that it has been a few years since he has used the PAC, and that he had only used a portion of the PAC (primarily the Sound module), but did not recall any problems with the PAC. He also noted that the other modules used in his class (such as the motion detectors for measuring speed of cars) also seemed helpful. It is logical that as time goes by the PAC modules would be upgraded, but overall the PAC seemed fine.

IMPACT OF THE TRAC PROGRAM ON THIS PARTICULAR STUDENT

"TRAC came along at the right time and was in the right place". The student noted that he was unsure of what he would do for his senior project, and the TRAC materials were extremely helpful in that sense. He noted that his high school was a math, science, and engineering - based institute, so the students naturally had an interest in that field, which is in part why TRAC was successful there. He pointed out that, "we did physics all the time".

COLORADO SCHOOLS

Volunteers from the Colorado Department of Transportation

BACKGROUND INFORMATION

The interviews with facilitators focuses on two areas: (1) whether there are civil engineering or transportation components not covered by the modules and (2) identifying the salient features of the modules that teachers find useful. In this particular case, three TRAC Volunteers and two TRAC directors from the Colorado Department of Transportation were interviewed together, and the attached indicates their collective response.

- The volunteers work with general science and physics classes in middle schools and high schools. The schools vary in terms of socioeconomic status and percentage of minorities, although DOE encourages involvement in schools with a minimum minority composition of 35%.

- Their role is to assist the teacher with bringing a real-world component to the Trac program.

- They have been involved with the TRAC program to varying degrees: two persons play a management role and three have worked directly with the PAC and the teachers in the classroom: one volunteer has been involved since 1996 and is currently between schools (this is his third year), one has been involved with the program for two years, and one is in her second year of involvement, although she has been aware of the program since it debut in Colorado. Her teacher has left the school so the volunteer has no school.

- Volunteers try to go every couple of weeks to the classroom; in one case a school has three volunteers so that every two weeks the DOT is represented by at least two engineers. (With two engineers in the classroom at the same time one may work with the PAC and one may work with the remaining students.)

- The PACs are currently used in about ten schools in Colorado, and it is noted that teacher involvement can be quite high.

- At one school in particular (Manuel High School), every three weeks teachers change emphasis from math and science to art and music to history. This works well with CDOT's emphasis on diverse transportation careers, such as consultants, archaeology, planning, and so forth, as well as the different positions available: engineers, technicians, landscaping, etc. Hence different elements from the PAC may be culled into each of the three week subject areas.

- The volunteer's role is to facilitate real-world involvement, but at one school the teacher simply wanted the volunteers rather than the PAC.
- It is critical that these PACs be used: the TRAC director received a grant to purchase PACs but questioned the wisdom of buying additional equipment until she could ensure that all current PACs are being used. (E.g. she might wait until after the PACs were taken from one school and given to another school to ensure full use.)

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

What are the strengths of the PAC?

- Generally activities that work are a plus. One volunteer pointed out that overall the experiments are well put together.

- In terms of *teaching* students, the volunteers pointed out that they view the goal of the specific PAC modules as encouraging students to solve new types of problems; the key is being able to work through an unfamiliar situation rather than something that has already been learned. (An example is being able to build a transportation component within constraints; e.g. there might be a limited amount of funds that need to be used to enhance transportation but are not sufficient for roadway widening or construction.)

- In terms of *reaching* students, the PAC is ideal in that it targets students who are not auditory learners but instead require hands-on instruction.

Yet difficulties with using the PAC include the following:

1. It is difficult to use with 30 students; ideally only 4-5 students should be working at a time on a project; the other 25 students have to be kept busy.

2. Less time on the computer would be nice as well.

3. The PAC materials should (but currently do not) work with some of the current technologies that are either available in classrooms or are becoming increasingly available, such as multimedia (CD-ROM, graphics, sound, and video tape), the Internet (especially for downloading information), networked computers (e.g. a proprietary software package that can only be used on one PC when other PCs are available is an anachronism), and graphing calculators which are becoming standard.

4. Schools have different needs; some need PCs, some do not: each school wants to choose their own curriculum and the materials that will be required will vary.

5. The PAC looks pretty low-tech: the DOS screen does not compete well against GUI (graphics user interface), multimedia, sound, and 3D graphics. Even though this is more like what engineers work with than the flashier applications, schools and students have been influenced by the “Microsoft” flashiness, even though all volunteers think the hands-on component is most critical. One volunteer found that the teachers were doing experiments similar to the TRAC activities but using different equipment, because they don’t like the PAC materials.

What characteristics tend to make a PAC module not be used?

1. The module does not relate to curricula being taught

2. Multiple disciplines are not included; the module relates to one subject area only.

3. There is no champion for using the particular module or the PAC.

4. Teachers don’t understand the module or how to do the activity.

Note also that the difference between a good module and a bad module can be how well the equipment works. With the sound module, you can come relatively close to the desired results. With the motion detector, on the other hand, the experiment is very sensitive to how it is set up: if you are not at the right angle or do not have well defined acceleration and deceleration with the vehicle, then the resultant graphs will be meaningless. This is why the motion detector module does not get used very often.

The PAC did not get around to the math teacher so they could integrate it into the classroom or to the social studies teachers so safety, planning, and social issues could be shown. This is being addressed more now.

What specific changes should be made to the PAC?

Teachers who use the PAC tend to be science and physics-based: math and social studies teachers do not see the value of the PAC. This is too bad, because the PAC modules really should represent a cross-curricular approach. To get around this problem, consider the following two options:

- Put the PAC on a cart. That did not work in one school when tried, but it has potential for encouraged sharing.

- Rewrite the modules from a multiple curricular perspective, even down to the activity level. For example, the "yellow light problem" could have a social studies component (e.g. where should you put the signals in the first place? Who wins and loses?) in addition to its current mathematical focus.

Additionally, the PAC is not as user friendly as it could be. Ideally, two other changes would be made to the PAC.

- *First*, it would be less teacher dependent: that is, students could do the labs without a lot of teacher assistance, whether they did the lab before or after the teacher's lecture. Thus, classes and labs reinforce each other.

- *Second*, teachers would be able to use the PAC very quickly even on the first try: if an experiment does not work the first time you plug it in and is not fairly intuitive, it is not likely to be used. Training, help manuals, and help screens can mitigate this problem, but realistically teachers will not spend a lot of time learning these activities. (At the training, teachers were reacting to TRAC saying "Oh no! This is going to take my weekends to learn this." They also did not want to get up in front of the students and be embarrassed because TRAC did not work. Also there is variation among teachers: some are very good at the setup and some tend to get lost.) Finally, consider some *simple but necessary* improvements:

- The PAC should include a printer so that teachers can quickly obtain output as needed.

- As suggested previously, the Internet is an excellent source of three items: updates to programs, evaluations of software packages, sharing of packages across a networked computer, and lessons about what works and does not work.

Instructions in the Manuals

The *instructions* in the manuals don't read very well and need to be made more reader-friendly with graphics, illustrations, and examples; one volunteer gave the example of using his old physics book to complement the manual. That physics book "sucks you in" and lets you learn more by looking at the examples and the graphics and seeing how it all comes together. Another example came from the Bridge Builder software: the book that comes with the software is more helpful than the student manual. The question-answer format found in the manual does not lead students toward the desired answer or pattern of thinking; the critical issue is that one wants a lab manual that helps students find the answer on their own.

One way around this problem could be to tie in the instructions with the teacher's curriculum on the subject. Students tend not to read instructions. Some middle school students had trouble with the reading level, although the school was mainly Hispanic and lower income. There should probably be two visions: one for middle school and one for high school.

Specific Modules

The *sound module* was really well put together and appreciated because of three reasons: *first*, one can introduce students to the concept of waves and frequency, *second*, one can take measurements with noises of various pitch (including the use of a tuning fork) and *third*, one can tie this in with a real-world example such as a sound barrier. Kids love to measure things – even counting the number of waves. The oscilloscope and decibel meter are similar in that students can see a real phenomenon and measure it themselves.

The *social studies* module (especially the role play and the town meeting) works very well.
Making safe cars out of soap, along with the *Maglev* module, did interest the students.

PC-solve is not used, although on a related note one volunteer expressed the need for some way of teaching students percent, especially in the context of roadway grades and slopes.

The students loved *Bridge Builder*.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

Hands-on activities are a plus as is anything the students can actually see. In fact, it is more important for an activity to be hands on than for it to be high-tech. Students learn by hands-on work! The volunteers did note, however, that once students are engaged in an activity, it would not hurt to have some flashy features that keep students attracted, such as 3D graphics.

Cross curricular programs are also very good. In the science Tsunami, an 8th grade teacher taught everything (math, history, English) from a science perspective. This was an ideal program.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

Tying the PAC in with the state SOLs is critical for its use in the classroom, and in fact Colorado has already done this. This is also something that can be done at the teacher training, where relationships between the PAC activities and state SOLs can be emphasized.

Teachers should be involved with curriculum development; they could offer a perspective on what is reasonable and what is not. This gets teachers thinking about how they would use the PAC.

Cross curricular activities should be emphasized, as these are important in the state SOLs.

IDEAS FOR FUTURE PAC MODULES

Several ideas are offered for PAC improvements in the future.

1. Write PAC experiments *at two different levels*: one for High School and one for intermediate school.

2. Look at *other providers of "neat" educational materials*, such as "Bill Nye the Science Guy", "Newton's Apple", PBS, and "National Engineer's Week" at http://www.eweek.org sponsored by the private sector, and structure the TRAC experience like those examples.

3. Add *a resource library of videotapes and laboratory equipment or materials.* Equipment from the DOT may be brought into the PAC, such as plan sheets and an EIS, which drove home the point that you cannot just build a road tomorrow but instead might spend several years planning for it! All kinds of other tools used in the transportation industry may be included, such as AutoCAD (where students might design a car on the PC), sets of road plans, a ball-bank elevation tiltmeter (which explains superelevation and helps students answer questions such as "what happens when you bank a road this steeply?"), examples of materials (core samples, reinforced concrete), and different beam types. (One can even make beams out of aluminum foil and copper materials and illustrate how loading changes these).

4. Inclusion of the ITS component was a good idea, but TRAC should have *an ITS component with an electronics emphasis.*

5. As suggested in (3) above, *consider low-tech examples that are interactive*, such as a beam breaker developed by an engineer that illustrates, through the use of a load against a beam and a shift in the position of the fulcrum, how much weight it takes to break the beam. This is like building a bridge and putting it under stress, but more illustrative of physics principles. It also incorporated materials testing. The volunteers noted that lots of other examples exist, such as string bridges across the room and a string of paper clips that allows one to create a pulley. This also led to the point, however, that many of the PAC experiments are duplicated elsewhere by other materials, leading to the policy questions mentioned later. SimCity is one such example; other examples could not be recalled but are strongly believed to exist.

6. *Volunteers should get with the teachers* while they are planning the semester's work to figure out where TRAC fits into the curriculum.

7. Make the "whole thing" *Internet-based*, as more and more schools gain Internet access, including lower income schools with minority representation.

8. *Give TRAC the "flashy Microsoft feel*" – have something like Bill Nye or the Office Assistant come on and tell students how to do the experiments.

WHAT IS TRAC's MISSION?

The goals of the program is a thorny question that all volunteers feel needs to be revisited. Officially, the goal of the PAC is to recruit minorities and women into engineering. Overall, though, after some discussion, two key goals emerged from the volunteers' perspective:

1. The program should get students interested in math and science, not necessarily engineering (although if students do become interested in engineering that's fine.) Math and science feeds into many careers; these subjects give students options later.

2. The program should open students' eyes to the diverse field of transportation: it requires not just engineers but architects, archaeologists, policy people, accountants, and other careers. This knowledge would help engineers become more well-rounded; hence whether a student is interested in engineering or not is less important for this second goal.

On a related note, one volunteer pointed out that with a key goal being to attract women and minorities into math and science, then TRAC needs to be done earlier, because by about 7th grade women tend to be told by their peers that it's not "cool" to be interested in math and science. In fact, even though TRAC may have been designed for a 10th and 11th grade level, by then at least half of the students are already being shunted on some particular track (humanities, science, etc.) and it's too late to interest them. They may not be thinking about careers yet; but their interests, in terms of course selection, are already set. Instead, one needs to reach students by about 9th grade if they are to be encouraged to pursue math and science.

There was some discussion as to the discernible benefits of a state participating in the PAC program. These volunteers pointed out that they cannot really measure of the acknowledged "lofty" goals such as improved recruitment potential, better public relations, or increased student interest in math and science or transportation. This is not to say that such benefits are nonexistent, but they cannot really be measured. Realistically, participation in the PAC may make the DOT look good in the public's eye and impress the state DOT's Commission (the governing board that makes major financial decisions) but as a practitioner, there are not discrete quantifiable benefits that can be attributed to the PAC program.

TRAC POLICY OPTIONS

The volunteers and directors felt that it is a bit premature to be looking at the PAC. While certainly PAC improvements are needed, there should also be consideration of the TRAC program as a whole. Hence consider the *following policy options; some do naturally encompass PAC changes, but some focus on how the PAC is implemented.*

1. Find a champion within the schools, the state DOE, and the state DOT to support the PAC. For example, at one school the engineers are actively involved and have periodic meetings with the school's advisory board. The TRAC program should be approached as a top-down effort, building management support and then working out the details. In fact, the volunteers felt strongly that the role of TRAC needed to be better defined before this particular project (to develop the next generation PAC) was undertaken.

2. Use Web-based technologies to update the PAC delivery system. Reconsider what we should be delivering.

3. Rethink the TRAC national goals: for example, schools are charged with implementing curriculum while volunteers, who are not teachers, can serve as role models for what one can accomplish in the transportation field.
4. Consider corporate sponsorships to provide funding, as state DOTs have limited resources.

Overall, though, TRAC is really more of an educational program than a transportation program. While of course it has an important transportation component to which a state DOT may contribute, the state DOT will not be acutely aware of curriculum needs and educational cycles that are the bread and butter of teachers, school officials, and state Departments of Education (DOE). In short, the DOT is not set up to be an administrative body like the DOE that provides materials, funding, and direction for teaching. (It should be noted, though, that at least one DOT volunteer serves on a school's advisory board, which helped coordinate the introduction of TRAC.)

There are many other programs competing against the PAC, such as natural resources careers and Colorado State University's efforts to increase minority student achievement. Hence schools are being bombarded by competing opportunities such as these, and each of these offerors has an interest in the outcome. In short, another way to think of the PAC is that it is a product of the TRAC business. As such, the PAC is in competition with other products; why not therefore break the PAC up into components so that schools can pick and choose what they want? This would enhance the strength of suggestions such as (4) above.

A PROPOSED TRAC MANAGEMENT MODEL

Before rewriting and redesigning the PAC, it should be decided how DOTs are going to delivery the product. A three way management model was suggested by one of the volunteer directors. He pointed out that currently the model works with TRAC National Headquarters passing materials and direction to the state DOT, which in turn gives information to the school. Hence in this series approach, ideas, materials, and curricula flow through the DOT. While this has been a good approach to get TRAC started in the Colorado area, two changes that have occurred within the past four years render this model unworkable. First, more suppliers of educational activities are available to schools today than were in the past: these suppliers include for-profit companies that sell educational aids, programs that encourage students to take an interest in some topic such as the environment or conservation, public educational outreach such as PBS or national engineers week, and Websites that are a resource for curricula and experiments. Second, state DOTs, such as Colorado are under a cycle of scrutiny with each election: a state DOT's management that thought a $40,000 investment in the TRAC program was worthwhile may be replaced a few years later by new officials who argue that the taxpayer's money should go to road construction. This has led to the volunteers looking for ways to determine how to make the TRAC program sustainable in the long term. One option is to ensure that the costs are absorbed elsewhere while the state DOT concentrates on its core business and contributes to the PAC what it does well – examples of how to use the transportation components reality – and leave what the state DOT does not do well – administration of educational equipment – to those entities who are better equipped to accomplish that responsibility.

As a result, a three way parallel model was suggested, where TRAC National headquarters is a resource for both educators and state TRAC volunteers. In this sense, TRAC national headquarters would provide, as desired by educators, components of a PAC as well as curricula directly either to the schools or to the DOE (which knows which schools can and would actually use the PAC). From the educators' perspective, there are several sources of materials and curricula of which TRAC is only one: other sources include PBS, private companies, Websites, etc. The TRAC headquarters would also provide advice and technical assistance to the state DOT which would serve as a “speaker’s bureau” or a repository of volunteers who would be able to give real-world examples about how math, science, social studies, archaeology, and history are used in the transportation field. The salient characteristic is that the state DOT would get out of the business of designing labs and supplying materials; instead it would be accountable for “being supportive to the schools as a socially responsible entity that provides volunteers” who bring transportation examples into the classroom. TRAC National headquarters would then be accountable for quality of the PAC as are other suppliers of educational aids. Schools would be responsible for student achievement; they would choose educational aids, which might or might not include the PAC, depending on how the aid would help the school achieve its goal of maximizing student performance.

A variant on this model that was also suggested would be that the DOT and/or the TRAC national headquarters would form a partnership(s) within the education community. The goal would be to take the educational materials that are already in use and customize them to the goals of the TRAC program.

Finally, there is a question as to whether the $15,000 annual fee that the state DOT pays to participate in the TRAC program is worthwhile, given that there is then a $4,000 cost per PAC on top of that effort and that schools do not have the option to purchase PAC components. It was suggested that telephone calls to states that do not participate in the TRAC program would shed light on whether or not the cost is the reason for not participating. Another way of putting this question is the following: “Is the way TRAC is implemented now a good model?”

Teacher from Colorado School 1

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs.

- The PAC is used as part of a regular classroom setting; it is integrated into the general sciences curriculum.

- This is the only teacher currently using the PAC. The physics teacher tried to use the motion fundamentals module but neither he nor the engineers could get the motion detectors to work.

- The teacher began using the PAC about three years ago at the urging of the principal; he has not had a chance to delve into it this year, however.

- TRAC offers three fundamental strengths:

  1. Students can see a person who uses these skills on the job; there is a real-world connection. Specifically, TRAC gives students the chance to participate in the school-to-career program.

  2. Students see the enthusiasm in a practitioner. Even when a bridge engineer comes and quickly gets over the head of 9th grade students by talking about the role of calculus in bridge design, the students can at least see (a) someone who is excited and (b) an application of school lessons in the real world. (Incidentally by the time the teacher trains volunteers to slow down a bit they leave his school and a new volunteer comes in). In short, even if students miss the scholastic concepts they at least can pick up on the raw enthusiasm of the speaker.

  3. Students see that education is a life-long activity that is motivating. The teacher points out that if you said "you will be in school for the rest of your life" most students–and probably many adults–would cringe in horror. Yet with the PAC, one can observe persons who are learning in a "fun" way.

  4. A realistic time frame is presented. Unlike school, one can see that horizons of 50 years are possible; a project can be so exciting or important that it is worth tackling, even if the results will not be immediately useful or available.

- *It was mentioned that at another school, the principal did sometimes tend to remove disruptive students from the PAC program as a punishment. The principal pointed out that this would not happen at this school, however, as TRAC is part of the class curriculum, unless a teacher specifically requested that a student be removed. This has happened in the teacher's experience only once in the past six years, and in that case the student was removed from all lab activity, not just the PAC.*

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

Overall, the PAC is part of a fundamentally good program, which is why this teacher has persisted. He notes, however, that the PAC is far from perfect and requires a lot of patience and troubleshooting.

Four PAC modules have been used or attempted,: *bridge builder*, *sound*, *Maglev*, and *motion fundamentals*.

The reason for using the *bridge builder* and *Maglev* modules is that it is possible to have some students working on those while other students are doing other activities. For example, when students are not crashing their car they can be redesigning it based on the results of the test. The reason for using the *sound* module, however, is very different: it is one of the few PAC activities that works as a demonstration! That is, even though students are all crowding around a single PC, the module "makes sense" as it is written as a demonstration. One of the success stories is where a xylophone from the music department allowed students to see the difference between frequency and amplitude and how these affect the sounds that are heard. Similarly, a musician who came to speak with the class noted that it was a joy to speak with the students as they seemed to understand the principles underlying how musical sounds are made.

Regarding the *Maglev* module, the teacher noted he could not find Styrofoam blocks that are thick enough even at the hardware store.

The *motion fundamentals* module illustrates where equipment failures can ruin a scientific concept as well as how they can be mitigated. It was originally desired to illustrate how acceleration and force are related, but the measurements with the force probes were extremely erratic. Fortunately, the teacher could convey a basic lesson with these data: as speed dropped, so did the force, whereas adding padding to the vehicle did not affect the force. Such an important lesson becomes applicable later when students are learning to drive; in this class, one student even added an anchor to the test car. Unfortunately, however, the nonlinear relationship involving momentum and velocity (e.g. as one goes from 40 mph to 50 mph the momentum increases not by 20% but rather by over 50% since the velocity term is squared) could not really be demonstrated because the readings had too much noise associated with them.

In short, Vernier needs to consider the problems with these probes: the teacher spent some time on his weekends trying to fix the problem but has not had sufficient time on his own to build a solution. Even something like a cone around the sensor would be appropriate.

Regarding the new PACs, though, the Windows-based activities are excellent.

Finally, *SimCity* is note used for two reasons: first, it does not seem feasible to use it as a demonstration nor as an individual station, since there would be nothing else for the rest of the class to accomplish. Second, it takes a long time to get started: a lot of work is required to build a city from scratch, and the pre-built cities are too complex to quickly understand. Yet having SimCity available on a network, however, would eliminate these two problems.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

As a teacher, there are three characteristics that must be present in order to use an activity:

- a *problem solving* component.
- a good *visual demonstration*, as is the case with showing a sound wave on the oscilloscope
- *support of the curriculum*. There is so much that must be taught that anything "extra" must directly relate to what the students have to learn. Note that in science, it is acceptable to require the students to read and write.

What activities tend to work?

Look at other programs, such as TOPS, Crystals, and Prism, and learn how they coordinate activities for students. One salient characteristic of these successful aids is that they appeal to different levels of student ability: there are some activities for basic students and some advanced activities; ideally a student who does an advanced activity for extra credit can report back to the class what was learned and, if it seems interesting, thereby encourage other students to do the same on future activities. The Crystals program is ideal in that it encourages open-ended thinking: students are given the problem and just enough background to ask intelligent questions, but the problem is not solved for them. One example that has worked well is a lab called "Isotope Pennies" where students are told four pieces of information:

- In 1982, the recipe for making pennies was changed, resulting in slightly different weights of pennies before 1982 and after 1982.
- the canister before the students probably has 14 pennies in it.
- there is one canister that does not have 14 pennies in it.
- a scale is available.

Without opening the canister, students are told to figure out how many pennies of each type are in the canister. This lab is excellent because it makes students undertake several problem-solving steps:

--what are the possibilities?

--what will we do?

--how do we need to organize our data? [eventually students figure out that a chart of the possibilities is helpful]

This is just one example of the many types of activities that are useful.

What activities do not work?

This question really depends on the dynamics of the group, but activities that are just too hard will be troublesome. When that is the case, one of two things will happen: either the teacher will not use the activity again or he will break it down into smaller, more feasible steps. This is why he likes a graduated approach to problem solving.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

As illustrated in the conversation with the principal, the teacher must be able to say that each classroom activity is covering a standard. See, for example, the National Science Teachers' Association summary of basic components. The reality of standards is that citizens are questioning public schools' ability to educate students. Unlike engineering, where you might judge the product by whether or not the bridge collapses, for education one of the few tangible indicators of product quality that is available in the short term is student performance on standardized tests.

It would be beneficial if the manuals offered some supporting information as to which modules relate to which standards. This need not be verbose nor too technical, but is best illustrated with an example. Currently, there is an English teacher who has been asked to teach science; she is attending night school to prepare, but in the meantime she uses the PAC as a potential source. That teacher may in her class be required to teach Newton's second law. The PAC manual should indicate which module covers Newton's second law, as well as what that law is in layman's terms.

IDEAS FOR FUTURE PAC MODULES

Several improvements should be considered:

1. **First and foremost, get a site license** for these software packages, such as bridge builder, so that they can be used at the school's computer lab. Unfortunately, individual licenses for these packages (PC-Solve, etc.) are extremely expensive. SimCity is not used but could be used in a networked situation. (For example, Bridge Builder costs $77 , PC-Solve costs $12, and SimCity costs $21). This cost of over $100 per PC is prohibitive in the classroom setting. Without PC-solve, for example, the calculus teacher who had expressed interest will probably not use the PAC.

2. It seems that either the software or the Vernier sensors are too sensitive, which ends up picking up too much noise. Consider, however, designing two modules: first, an "idealistic" module that oversimplifies reality and smoothes out the curves, such that the basic principles (e.g. changes in acceleration) are illustrated. The second module could then focus on all the background noise that is always present. That way in the first module students would learn a concept and in the second module they would see realistic limitations.

3. Figure out some way that middle schools can feed into the PAC, so that modules which are done at the intermediate school level can be expanded, rather than skipped, at the high school level.

4. To involve other teachers, use networked software, graphing calculators, and Internet modules. The school does have a computer lab, which the teacher can access provided he knows in advance that certain modules will require the lab; he also needs to prepare his students for a trip to the lab.

Several new modules may be added as well.

- *Add An Internet module*. Note, however, that was is suggested here is a bit different from simply using the Internet to gather information. As stated previously, even if concepts are beyond a student's grasp, a practitioner's enthusiasm is contagious. The Internet should be used to make transportation "come to life", with students ideally being able to find out about ongoing research projects, such as space exploration or Maglev deployment tests. Then, it would be appropriate to provide the class with live downloads from the test site: students could ask questions of the scientific community. Since they are already familiar with chat rooms, the idea of using this same technology to interact in real time with ongoing transportation projects – and the practitioners that are involved – is very exciting.

- Include a *technical writing* component. Students need to know how to interpret a technical manual.

- Add a *budget/accounting* component in with the bridge manual.

- *Include* writing a proposal *as a module: students should integrate cost analysis, design requirements, report-writing skills, data, and a real-world problem such as designing an automobile into a report that others can understand.*

- *Cross-curricular* activities are a good thing!

Principal from Colorado School 1

The purpose of the interview with a principal is to identify generally the factors that affect whether or not an educational aid, such as the TRAC PAC, will be used by the school. Hence the principal is able to offer insight from an administrative angle.

FACTORS DETERMINING WHETHER AN EDUCATIONAL ACTIVITY IS TO BE USED

First and foremost, we need staff development and training; the provider of the educational activity must demonstrate a strong interest in teaching teachers how to use the curriculum in the classroom.

Second, the educational aid must help student achievement. This can be accomplished by ensuring that the aid correlates with the curriculum or standards of learning used by the school. The teacher and the principal together gave an excellent example of a standard: the teacher uses a module from the PAC that involves the bridge builder software. The principal asked "what standard does this meet?" This is not a trivial question:

- At one level, the teacher is able to say that this meets the "lab content" that is required, since his course must have some amount of laboratory time.
- From a curriculum perspective, the lab teaches Newton's law and force vectors, which are required in the physical science course
- From a specific standards perspective, the standard being met is "be able to interpret and make a force diagram."
- From a general standards perspective, the standard being met is "be able to interpret graphic materials and scientific drawings."

Third, there is an increasing emphasis on "technological literacy." This means using technology in a variety of subjects – physical education (P.E.), music, math, and science, to achieve a desired result. Not that this does not mean watching a videotape; instead, it is desired that students actively manipulate a tool: an example is working with instrumentation in a P.E. class to monitor changes in heart rate before and after exercising. In this vein, teachers are encouraged to use technology for instruction; practical examples include software applications, databases, spreadsheets, and graphing calculators.

It is important to recognize that students may not use the technology unless the teachers use it and are comfortable with it.

INSTITUTIONAL CONSIDERATIONS

Officially, this particular school district has four distinct goals:

1. the *school-to-career* program, which emphasizes workplace standards that students should be able to achieve once they leave high school. The standards cover five different sets of skills: communication, organizational, thinking, worker qualities, and technology.
2. *literacy* (reading and writing)
3. *school readiness*, which is basic skills that you need to survive beyond high school, and
4. *community involvement*.

It is noted, however, that the first two goals -- the school-to-career program and improved literacy – are the most significant.

One other concern is the issue of "scheduling design" problems in the school. Can the instructional aid be used in the classroom situation? Logistics-wise, is there enough space for the equipment?

Finally, one caveat regarding the use of technology in the classroom is appropriate: *there are some teachers who do an excellent job of teaching without technology.* One example is a social studies teacher who every class lectures from the podium. Yet a student explained that each class was inspiring; the lectures were well done and helped form a mental picture in the student's mind. The point here is that high school teachers are expected to convey material in a variety of different formats to capture students' interest: lectures will work for some, hands on lessons for others, and still others will benefit from reading interactively.

Teachers, Lab Personnel, and Volunteers from Colorado School 2

This meeting was held at different locations throughout the school as persons came and went. The interview was originally started with one social studies teachers, one volunteer, and one educational representative, two of whom were already meeting for another purpose. Then, a visit to the technology lab brought in the technology lab leader; then that leader and the educational representative left and a physics teacher later joined the meeting, which had moved to his classroom. While waiting for that teacher, another physics teacher briefly provided some information regarding prior use of the PAC. The state TRAC director was present for the entire meeting.

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs. Manual's usage of the PAC is a bit unique in that the greatest emphasis of the school is on careers.

- The PAC has been available for the past three years, although it has not been used very much.
- Last year Manual began a "Reform" program that focuses heavily on career explorations. The school is divided into two halves: the Foundations House (9^{th} and 10^{th} grades) ensures that students grasp basic skills that are essential to survival, and then the various Programs of Excellence (11^{th} and 12^{th} grades) allow a student to focus on career areas of his or her choice, such as:

    --business, finance, and telecommunications

    --math, science, and medicine,

    --arts, humanities, and communications,

    --cultural studies and government.

- There are two distinct categories of PAC usage that are feasible. One area is in the more traditional route: using the PAC as an instructional aid within the classroom; in this instance, it is used as a laboratory module in the physics course.
- The other type of usage, however, is as part of the school's *technology lab*. The technology lab has a variety of workstations: virtual flight, ecology and environment, transportation, SimCity, Lexus Nexus, Quicken, networking, computer programming, web page design, desktop publishing, video productions, advertising, CAD, biotechnology, meteorology, gardening, and transportation components of the PAC (SimCity again, bridges, and uses with the probes). Different classes of students are planned for visiting the lab at various stages: 9^{th} grade is for demonstrations, 10^{th} grade entails 90 minutes per work station per day over a 4.5 week period, and 11^{th}-12^{th} grades entails extended study with each workstation. The lab is not yet ready for the 11^{th} and 12^{th} graders but work is underway.
- The lab is used in conjunction with other classes. At the 9^{th} grade level, students can take an 18 week, 45 minutes per day career exploration class, including guest speakers and demonstrations at the tech lab. At the 10^{th} grade level, students visit the lab as part of their fundamentals of leadership course.
- The Community College Occupational Education System (CCOES) representative noted that additional standards of learning are available at the state level; these represent a linkage between state legislative standards and educational curriculum that is used statewide. A memorandum of understanding has been signed between the state DOT and CCOES that addresses how one may coordinate the training of new teachers.

- The social studies teacher has a math degree, which gives him a good background for digesting some of the technology and PAC areas.

- The school's demographics have changed: basically there is about a $20,000 drop in household income when one crosses from any of the neighboring school districts to this one.

- Problems with lower test scores have lead to the aforementioned reform; a grant from Kellogg to make leadership a focal area has been helpful as well.

- The school is finding that with the technology lab and career emphasis, students in the 10th grade are already thinking about careers. In the 9th grade, the students make an academic plan (ICAP) to investigate careers; they update this plan as they gain experience. The school hopes for job shadowing and partnerships with businesses for 11th and 12th graders. One way the school hopes to evaluate its reform program for the 9th and 10th graders is to see whether they sign up for physics or chemistry in the 11th and 12th grades.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

Technology Lab Usage

The technology lab has two main goals: ensuring that math, science, and physics are shown to relate to career choices, and getting students interested in those subject areas. Two PACs with computers are being used in the tech lab and the lab teacher feels that TRAC fits in very well. The PAC modules that will be used this year in the technology lab include the motion detectors and SimCity. Although this is the first year of operation of the tech lab – and hence not a lot of information on the PAC is available – some insights may be gleaned by how the PAC will be used.

- The technology lab coordinator is a full time employee who focuses on keeping the lab equipment and curricula functioning properly. Not only does she troubleshoot when materials fail, but she also makes sure lesson plans are workable with the students. Therefore she has taken educational aids from different sources, such as Paxton*[-Patterson*] and the PAC, and separated the various modules. While the school tends to pull this coordinator into other classrooms when there is a personnel shortage, the lab is currently her focus.

- The coordinator spent approximately two weeks rewriting the labs, identifying every conceivable pitfall so that the students may work on the labs without assistance. For example, the manual used to read "set up the probe about ½ a meter from the top of the track" without specifying exactly where the probe should be placed. Overall, though, the first time through a module is hard.

- The coordinator is also rewriting the labs so that the "Paxton" philosophy is followed, where students are given some basic information but the question is not answered for them.

- Overall the PAC fits well into the technology lab, especially the activities that make use of the probes.

- More PACs, PCs, and equipment are always desirable!

- As stated previously, the lab is only for 9th and 10th graders right now, but in the future 11th and 12th graders would be provided with more study. The central question facing how to do this for the higher grades is "how do you develop higher level skills with these workstations?"

Classroom Usage

- One physics teacher briefly stopped by the meeting; he had been to the original training and who used to use the PAC, noted that it had been used in the physics classroom to increase student interest in physics. (The probes worked with 9th and 10th graders, encouraging them to sign up for physics in the 11th and 12th grades). The sound module was the only one he could recall using; in the past the sensors and probes had had limited use.

- Another physics teacher who currently uses the PAC, focuses on sections 2 and 5 (*motion* and *sound*). The math modeling (*PC solve*) was skipped, as it repeats what is done in the mathematics class with graphing calculators. The teacher thought that *SimCity* and *Bridge Builder* work well with stations, but are too long to use unless you have nine computers. (They tend to be time consuming to get setup, especially for students who aren't very good on the computer.) Overall, the physics teacher would not change much in the PAC. If stations are to be used, one wants four persons per group.

- The teacher uses the PAC as one 15 minute rotation, which works bets when the volunteer is there, since she can stay back with the PAC to answer questions.

- The most useful functions of the PAC is that it can be related to a career (e.g. civil engineering) and provides students with a hands-on experience; it's a good break from "physics, physics, physics." For example, one can learn that a change of 5 decibels is actually a lot of noise as it represents a logarithmic scale. Incidentally a comparison was made between noise in the hallway and noise levels on I-25; the two are equivalent! This career emphasis makes the PAC unique compared to other lab providers like Paxton.

- This teacher noted that as long as one uses good technique and some common sense, one can do the PAC experiments without much difficulty. For example, once you understand how a piece of equipment works (a data logger or a probe) you can use that same knowledge for a variety of situations. The idea that probes could be too sensitive is "ridiculous." The teacher also noted that his previous experiences may have helped with some troubleshooting, that the setup is time consuming especially the reading of the manuals, and that one needs a big target for the probes. Overall, though, his view is that the keys to success with the PAC modules he has employed are common sense and good experimental technique.

- The PAC *student manuals* are followed pretty well as they and the Pasco manuals are written at the current grade level. Some students read below this grade level, however. It was noted that Herlihy is most digestible for the students.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

One should look at other suppliers of educational materials, such as the Biotechnology module from Paxton, Pasco Scientific (972-403-0282 or 800-772-7600), Vernier, Herlihy, and AES for different types of ideas. The teacher also could recall work with GPS and CAD. The physics teacher really liked the Vernier equipment and software, which came with a site license and is very inexpensive. Pasco is doing roughly the same thing. One characteristics that teachers look for in the labs is variety.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

In the technology lab, the components, including the PAC modules, must fit within the specific careers for 9th and 10th grades. For the 11th and 12th grades, it will be necessary to determine how to take these modules, including the PAC, to a "higher" level, so that students may develop certain skills more fully. These advanced modules would need to fit within the Programs of Excellence (POEs).

In the classroom, the physics teacher noted that the PAC aligns fairly well with the SOLs in terms of the velocity and acceleration graphs from the motion detector. There is a section in the physics standards on kinematics which corresponds well with TRAC, as does the sound portion.

IDEAS FOR FUTURE PAC MODULES

The physics teacher noted that one might be able to add several modules: aerospace/aerodynamics, materials testing (e.g. elasticity, Young's modulus, stress, and strain), graphic design, GPS, and air transportation. The existing modules should be retained, though (or at least the ones this teacher has used). The volunteer mentioned that while TRAC should not try to compete with Paxton, that company has a biotechnology module that is really good, including a statistical analysis for quality control.

Teachers and Volunteer from Colorado School 3

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs. Two teachers and one volunteer were present at this Middle School.

- The PAC has been in the school since January 1998, so only a few activities have been attempted.

- Since the school district is not providing sufficient funds for these activities, private donors and other public agencies have to "take up the slack" and provide either funds or equipment. Examples of other suppliers include grants from IBM and U.S. West's technology program. In short, it is very difficult to "get what we need in education."

- Note that especially at the intermediate school level, teachers don't know until 2 or 3 years later that an activity worked. For example, a few years ago the teachers did an activity that involved laying out a floor plan for a house; later, in high school, a student decided to go into architecture because of this activity she had done back in 8th grade. Yet the teachers only happened to hear that this "floor plan" activity was successful by word-of-mouth. Similarly, a student won a space camp scholarship based on a significant amount of help from the TRAC volunteer with the application as well as being able to draw on her PAC experiences; again, the teachers only found out about this by chance.

- The PAC is used primarily with extracurricular activities such as MESA, the Future Cities Competition sponsored by the local chapter of the Society of Black Engineers, and the Rocket Club. Sometimes there is a direct linkage between the PAC and these activities; for example, in the case of the Future Cities competition, the students use SimCity 2000 software just as they do within the PAC. (The competition is more robust than simply using the software, though: teams of students write a 100 word abstract, a 500 word essay, build a physical scale model of a section of the city they designed with the PAC, and make an oral presentation.) In other cases students are told the PAC is where they can get more involvement: for example, with the elementary school-based Rocket Club, students learn about Newton's three laws of motion and then are told "if you want to learn more about transportation when you get to intermediate school, then go find out about the TRAC PAC."

- An unusual situation occurs at this school: the 110 students that participate in the MESA (Math, Engineering, and Science Association) program are taught by four teachers, from the areas of math, science, English, and social studies. The students are a group that the teachers know are already interested in math, science, and engineering. Introducing them to transportation engineering provides the best chance of "working" with this group. Two distinct benefits arise from this situation.

    1. The teachers *work together*, meeting once a week to determine how to best coordinate their lessons for the students. The result is cross-curricular activities; a student may approach one problem from different angles within the school.

    2. The teachers *jointly use the PAC*, getting input from the TRAC volunteer who comes to the school once a week. The result is that teachers gain an understanding of how to use the PAC modules for all four subject areas rather than only math and science.

- Note that MESA also includes an after-school club that focuses in greater detail on math, science, and engineering. One teacher uses TRAC with this group after school, especially SimCity and Bridge Builder. She also works with the aviation club and might use TRAC there.

- The volunteer's role is to provide real-world examples as well as serve as a link between these students and students who are younger. The volunteer also passes on tips to the teachers for using the PAC, but is not responsible for doing the actual modules.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

The teachers have not had enough time to use all of the PAC modules, but they have had a chance to experiment with the *motion detector* and the *sound module*, and this year they hope to use SimCity along with the Bridge Builder software. One teacher had read the yellow light problem and thought it was great: it's a simple idea (perception time plus reaction time) but the math was too complex for the students.

Note that getting the ramp to the right height in order for the motion sensors to work is time consuming. More ramps and cars are needed to use this lab in the classroom. Overall, though, more activities like the ramp would be appropriate.

The sound module is good in that it exposes students to concepts but it is not clear how to tie this in with the curriculum. Later it was pointed out that the use of sound barriers would be good for incorporation within the PAC.

Real-world problems such as the yellow light activity are excellent; teachers need more examples of what are realistic transportation-related problems.

One complaint is that with just one teacher and one PC, it is hard to keep a classroom of 25 students interested; one will end up with 2 or 3 kids staring at the computer while the rest are bored. Consequently the PAC needs to be just one of several activities concurrently undertaken in the classroom if it is to be used in its present form. The teachers don't want to just use TRAC as a free-time activity but would rather incorporate it with the curricula which is difficult in TRAC's present form.

Second, a room would be ideal for the PAC equipment. It's a pain that you have to set up and take down equipment on a daily basis, and with the recent theft of some video equipment, a lot of the rooms are not secure. Ironically, though, additional equipment would probably solve this storage problem, because with lots of equipment it is easier to make the case that a storage room or a math/science/computer room is required. This is especially important since TRAC cannot be part of the technology curriculum: the technology lab that U.S. West bought the school is booked most of the time.

Third, the modules are sometimes too advanced for the 8th graders. It seems that one module for the intermediate school level and one module for the high school level would be appropriate. The teachers feel that one could not wait until 9th grade to introduce students to TRAC; the light bulb needs to be turned on "pretty early." In designing a program that goes from middle (6th-8th) to high school (9th-12th grads), six years is a pretty long period and the students are radically different in their abilities. A single program may not meet all their needs. Hence if you can only do one program, do it at the middle school level.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

*The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids **besides** the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

In short, hands-on real-world problems are needed that will make math less of an abstract concept.

Getting the students to see math and science in action is a very useful experience! Students just don't learn any more from paper and pencil problems like they did a generation ago; instead you want to get students doing activities and then not even let the students know they are learning math and science until they are in the middle of the activity. Presenting mathematical equations is just too complex at this stage; at this level, student have not made the connection between math and science. TRAC addresses the needs of this generation.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

Tie in year 2000 standards that are being promulgated at the national level and which are mandatory next year.

IDEAS FOR FUTURE PAC MODULES

The teachers offered some suggestions here, but they also noted that it is the engineers' responsibility to come up with some ideas of what the PAC modules should contain. As teachers, they believe they do not have sufficient experience to state what constitutes a "real" transportation-related experiment.

It would be nice to add an aviation module, such as a simulator or some other tool that illustrates how actions such as changes in velocity (e.g. braking) are measured. This would help students understand the significance of negative numbers.

A GPS module that illustrated both high-tech principles, such as how the satellites can triangulate to find a location, as well as a more historical approach covering how Christopher Columbus used triangulation to navigate his ships, would be appropriate. The students saw GPS at work during a pilot program at the Ch engineering school and loved it.

Runaway truck ramps would be good; not only can they teach about physical laws but they can also teach students about the real world. Many of these students have not traveled beyond Denver and have not seen these truck ramps.

Finally it was suggested that engineers who know the field and their profession should submit appropriate modules.

Students of the Math, Engineering, and Science Association for Colorado School 3

Three intermediate school students (one sixth grader and two eighth graders) were interviewed about the PAC modules they had used: SimCity and BridgeBuilder. The students were actually using these packages at the time of the interview, and in the interviewer's opinion, they seemed the most comfortable talking about these two packages. In our view, the opinions expressed regarding SimCity illustrated the depth of imagination that students may have, whereas the comments regarding BridgeBuilder illustrate that not all concepts presented within a software package will necessarily be learned.

Comments on SimCity

The nice thing about SimCity is that there is lots of variation. With the simulation, for example, you can create your own city, including naming the stadium (we called it the Noisy Crickets), adding colleges, adding beaches (a unique item in land-locked Colorado; we called our beach Cherry Creek Reservoir), building ports (Port Mesa), theme parks (Riverside Mesa), and that type of thing.

Also you can see your score; we got as high as 1900 (out of 2000 possible points) before our entire town was condemned!

Comments on the Bridge Builder Software

One student felt that overall it's not as interesting as SimCity: if I were redesigning it, I would add options such as different type of bridges (not just a suspension bridge but a concrete bridge or a rail bridge), as well as a drawbridge option: when you think about it, how will tall ships pass unless there is a drawbridge? The other two students, though, thought the software was interesting in that you could see action on the screen, such as the bridge collapsing when there was too much weight.

Since the students were actively using the Bridge Builder software, the investigator asked them what the various items meant at the bottom of the screen. These are shown when one is designing the bridge and when one is testing the bridge with the truck rolling over it.

While all three students knew that "length" denoted the length of a particular member, they did not all know the meaning of the other parameters shown when designing the bridge, such as the member number, the size of the member, the difference between allowable and actual force, and efficiency: one felt she knew those terms but the other two did not.

The second bridge builder screen had parameters such as grid coordinates, delta x and delta y, length, angle, and bridge weight. While one student felt confidant with these terms, the other two had not had graphing and asked what "x" and "y" meant. They were generally able to figure out what "angle" meant by graphically moving the member and seeing how the value of the angle changed; they did this at the prompting of the interviewer. There did not seem to be a clear understanding of the "kips". Finally, when asked what "efficiency" means, one student stated that "lead is too heavy for a balloon, but latex is better because it is lighter."

Principal from Colorado School 3

FACTORS DETERMINING WHETHER AN EDUCATIONAL ACTIVITY IS TO BE USED

There are two main goals that we would like to achieve at the intermediate school level. First, we want to ensure that students have achieved the basic facts of mathematics: addition, subtraction, multiplication, division, estimation, and other skills that will give them a decent shot at passing algebra and geometry. (Note that students have the option of taking algebra in the 8^{th} grade; if they do poorly they can take it in the first year of high school – 9^{th} grade.) The second goal is that students would gain some problem-solving skills: this entails a hands-on approach, authentic tasks, and critical thinking. By "problem-solving" the principal means five discrete characteristics:

1. *multiple steps*. For example, if we are asked to paint this room, determination of how much paint is required is not a single computation but instead is comprised of several tasks: deciding what will be painted, taking measurements, figuring out area for walls and ceilings (but not necessarily the floor), and then dividing in order to determine how much paint to purchase.

2. *consideration of alternatives*. In the event of alleviating congestion, one would reflect on carpooling and a light rail system in light of the fact that the city is spread out.

3. *divergent thinking*. It is here that the creative process is employed in identifying multiple solutions; math tends to encourage convergent thinking (one right answer) but in reality influences such as the political process mean there may be multiple correct answers.

4. *getting all the facts*. There may be a lot of angles to the problem, and they are not all restricted to one discipline. In fact, even though the PAC may have a strong math emphasis, it would be excellent if multiple disciplines could be addressed within a single problem-solving module.

5. *organizational skills*. It may well be appropriate to establish an agenda or schedule outlining when the different steps will be taken, or who will accomplish them.

Mathematics especially would benefit from some real-time problems that have these components, especially if they can pique student interest. The "good" students who do not need help with algebra or geometry are going to do fine regardless; it is the weaker students who could really benefit from some real-world problems. In transportation, for example, one could consider geometrics [e.g. roadway design] or, as has already been done, determining how the area that used to be the airport should be used.

Cooperative learning (e.g. group work) is appropriate if and only if multiple students are all learning, with each student doing a specific task. It does not work if the "group leader" ends up doing all of the work!

INSTITUTIONAL CONSIDERATIONS

Follow the "keep it simple" principle: teachers will tend to use a new curricula or activity if the activity is easy to use. If training is provided, probably all teachers will tend to try the activity at least once; if training is not provided, then probably on the younger teachers or those with a technological bent will attempt it. As an example, when Macintosh computers became available they were easier to use than were IBMs; this explains the prevalence of Macs in some schools today even though IBM-compatible PCs have a stronger market share.

If the instructional aid is to be sold, then at least in this school district the aid must have been piloted in schools and shown to be helpful in raising student achievement. If raw data are not available, then the proof must come from teachers' testimonials stating how helpful the aid is. In prior experiences where a new educational activity has come into the classroom, achievement gains that were recognized may have originated from the fact that students were getting additional help or attention that came from the aid rather than the aid itself.

Schools have a lot of programs going on, and PAC partnerships rather than competition with these programs may be worth considering. For example, the Federally funded school-to-career program or similar ongoing effort may be a suitable avenue for the PAC. In response to the interviewer's question about gauging for how long a program or idea will be in vogue, note that two topical areas – *businesses/careers* and *technology* (graphics, keyboarding, interpretation of data) – will not go away and represent long-term interests of schools.

Keep in mind that a school that has a program must use it! In one case in this district, a school is losing its computer-emphasis program because although the school had been a magnet for students interested in computer programming, it was found that a lot of the students were attending the school simply for the diploma and not taking any computer courses. This district does offer other types of concentrations, such as international relations.

By the time students get to high school, they tend to think that activities such as a role-play, mock trial, or mapmaking are "uncool", whereas in middle school students will be more likely to do these types of activities. Hence in high school, students are more used to lectures and notetaking. This is not, however, as things should be; it would be beneficial if some more hands-on non-lecture-based activities could be included even at the high school level, such as the egg-drop competition. For high school students, it may be appropriate to focus on making activities even more true to life, with students taking on real issues. This does not preclude doing the same thing at the intermediate school level: in this case, for example, the principal is actively pursuing coordination of an ecological problem with a nearby university: the intermediate school has a cockroach problem, and the university has purchased parasitic wasps for a research project. The wasps lay eggs and then the offspring eat the cockroach eggs but within 8 days die themselves. This ecological method of controlling roaches would make an excellent candidate for involving 6^{th}, 7^{th}, and 8^{th} graders with real-world applied scientific research. In short, a review of the basic facts is good in high school, but solving real-world problems is appropriate for multiple disciplines, especially math.

SOUTH AFRICAN SCHOOLS

TRAC South Africa Representative

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs.

Although some aspects of the TRAC program in South Africa are similar to the program in the United States, the focus of the program is quite different. This is due to the fact that the South African educational system faces different challenges and therefore has other needs than the American educational system. According to the representative, the educational system in South Africa has to overcome some huge obstacles at this time.

There are a number of “established schools” which are reasonably well equipped, but there are also “developing schools”, which lack facilities and qualified teachers. These developing schools have to deal with problems such as security (theft of computer equipment is a problem), the computer literacy of teachers, and overall science and mathematics instruction, and are looking to enhance the programs they have. It is also important to remember that many classes consist of 40 or even 50 pupils, making it difficult to use the TRAC PAC other than a demonstration model. These pupils also study in English, but for many of them, this is not their mother tongue and thus they have to overcome the language barrier.

TRAC has been used in South Africa since 1994, but most of its use has occurred in the last two years. About 40 schools have used the program for at least 2 years. Three full time trainers have been hired, one in each of the regions, to train and retrain teachers. This is due in part to the fact that many teachers are leaving the profession. (It appears that once teachers are trained, they are less likely to not use the PAC, and the representative has observed gradually increasing confidence in the PAC which he attributes to the training).

TRAC is currently introduced into schools by inviting teachers (and some of their pupils) to an introductory session, where the South African Introductory Video is played and some of the activities are demonstrated and can be used by the attendees. Schools that wish to participate must then submit a “motivation” stating the number of students, the level of teacher support offered, how TRAC would be integrated into the curriculum, what type of security would be used to safeguard the equipment, whether the school has an infrastructure that can support TRAC, and how TRAC would enhance community development, especially in developing schools. If a school receives the PAC but fails to use it, it is given to another school.

There are about 15 sponsors of TRAC in South Africa. The two main sponsors are the South African National Roads Agency and the FHWA. Other major sponsor include the Civil Engineering Industry Training Scheme, the Department of Trade and Industry initiative – THRIP (which matches funding raised from the transportation industry) , the petroleum industry, and individual construction contractors. Sponsors are often looking to contribute to the developing schools, to increase the qualified human resource pool from which they can draw, and to demonstrate that they are working to further community development. Sponsorship is coordinated centrally, but some schools also raise money for the program themselves. Up until now, the state department of education has not been involved in the program. The developers felt that they wanted the program to be well established before bringing another governmental unit into the process. However, a research project similar to the current NCHRP project will be run by an educational specialist affiliated with the University of Stellenbosch and will be staffed by teachers.

There is a dire need for engineers in South Africa, so many schools are concentrating much of their effort on science and mathematics. Mr. Blue[*] feels that TRAC cuts across too many school subjects: it is critical that we not soften science too much, but instead illustrate *how to use technology to solve problems*. He is pleased if two

[*] Not his real name.

teachers per school can use the TRAC PAC and feels that one cannot expect all teachers to become proficient in the use of the program.

The mission of TRAC in South Africa is twofold: *first*, to enable pupils by contributing to the school's ability to offer technical education, and *second*, to encourage pupils to pursue civil engineering and transportation careers by increasing student awareness. Mr. Blue felt that these objectives differed somewhat from TRAC's objectives in the United States, since in South Africa, enabling educators was just as important as encouraging career choices. It was his impression that the original TRAC PAC had been developed by members of the transportation industry to meet the needs of this industry without a great deal of educator input.

COMMENTS ON SPECIFIC TRAC MODULES

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

Improvements for the Student's Manual: Each activity in the Student Manual needs to be one page, in the form of a worksheet that teachers can copy and hand out. This will minimize the copying required and reduce teacher costs. The next step would be to produce a video for selected activities.

Instructor's Manual: In addition to making it clear where a particular activity fits into the curriculum, the Instructor's Manual should include more information about the modules for teachers. For instance, under vehicle momentum, the students are asked to determine the mass of the vehicle. Teachers need to know exactly how this is to be done. There should also be some discussion of possible answers that students are likely to mention in class. On a related note, Mr. Blue also recommended that an instructor's video be made illustrating exactly how the equipment is set up and run. South Africa has to do a lot of retraining of teachers since many schools are experiencing a high teacher turnover. Teachers could refer to the video immediately before conducting the activity.

Magnetic Levitation Module: Mr. Blue feels that the Maglev module is only a small part of TRAC and shouldn't be a major topic in the TRAC introductory video. The utilization of Maglev does not justify its place in the TRAC PAC.

SimCity Module: Although the South African educational system is moving away from passive learning toward an outcome based, creative problem solving approach, activities must still fit well into the curriculum to be used. SimCity is a very good activity, but it is not directly related to the science and math curricula, and students must work at it a long time to get any results. SimCity is therefore usually played on the student's own time. He also felt that site licenses for these simulation programs should be available so that they could be installed on the network or in a computer lab.

Bridge Builder: Mr. Blue felt that there were other activities, like Bridge Builder 2000, that produced quicker results than SimCity. It is more directly applicable in science courses and deals with a definite engineering problem. Not long ago, Mr. Blue attended a science fair also attended by some very disadvantaged students from developing schools. Many of these students had never actually seen a computer and were unfamiliar with the concept of using a mouse. Not only did they seem to relate well to Bridge Builder and enjoy the simulations, but they also seemed to develop mouse skills. He also mentioned that Bridge Builder was useful in presenting the concepts of compression, tension, and stress. He had two suggestions for improvement: he felt that a running total reflecting weight and cost should be added to the program, and he also felt that measurements should be in metric rather than Imperial units. This suggestion applied to all of TRAC, since it is science-based program.

PC Solve Module: Mr. Blue felt that PC Solve was overly complicated and costly in light of what students got out of it. It is also presented in an outdated black and white DOS environment. He was surprised that the TRAC PAC didn't include a spreadsheet, since this is essential software for any student in science and mathematics. The TRAC file could be put on a spreadsheet, although he did not favor reformatting the problems. He has seen two other packages he feels are better than PC Solve and which address needs not fulfilled by a spreadsheet. The first is an interactive database program that asked for input as questions and offers the student a more user-friendly environment. The other is intelligent software that follows and scores the student's efforts to solve a problem, and steers them back on the right track should they head off in the wrong direction.

Finally, note that when querying teachers, one must consider that they are unlikely to complain about a piece of equipment: they are thankful to have it! Hence Mr. Blue points out that investigators need to "look below the surface" at what teachers are saying about the PAC.

The sensor equipment (motion detector, microphone and force probe) is very popular with the teachers and students. It is perceived as a useful tool for illustrating some abstract physics principles.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids besides the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?

What should be encouraged? In order for modules to be used, they have to meet three criteria: be easy to learn and set up, use locally available materials, and directly support the curriculum.

What doesn't work? If it takes too much of the teacher's time to become acquainted with the material (like PC Solve) or too long to prepare for before class, the expenditure outweighs the benefits and teachers won't use the modules.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

Mr. Blue felt that because the original TRAC PAC had been developed by transportation professionals, it may not have adequately addressed the needs of teachers, who are interested more in education than in transportation. Teachers in South Africa follow a standard syllabus (not unlike standards of learning) very closely. Although they feel that it is good to include interesting transportation technology activities, they need to figure out how to fit them in their curriculum. Currently, there are superficial indicators of where the 42 activities might fit in, but Mr. Blue feels that the next TRACPAC should be designed for educators and specifically designed to fit into the science and mathematics curricula. For instance, it is clear how the movement and sound activities fit into the curriculum and thus, these are often used. SimCity is also very good, but because it is less clear where this fits into the curriculum, it is less often used in class and more often used by students on their own. In short, illustrating exactly how a module ties into an SOL will make a big difference.

IDEAS FOR FUTURE PAC MODULES AND CHANGES IN THE PROGRAM

- Rather than send a new computer along with the TRACPAC, *use the hardware already available in the school*. This keeps costs down and reduces the security problem in the school.

- TRAC should be more *self sufficient in terms of training*. If Microsoft had to train (and retrain) each user every time they tried to use Windows, they wouldn't be in business. A training video illustrating how to set up and run the TRAC PAC equipment would be useful as a refresher for teachers using TRAC a few months after initial training.

- South Africa has recently set up an email based *users' group* for TRAC, where teachers can ask questions and share ideas, and the administrators can post new ideas and frequently asked questions (FAQs).

- The *applicability of the TRAC PAC should be expanded*. The more applications there are for the TRAC equipment, the more likely it is to be used. For instance, there are lots of Vernier probes in addition to the ones included on the PAC. If some of these were included (or if multiple probes of the same type were included so everyone in the class could use one), more activities would be completed.

- *The utility of the PAC should be measured.* South Africa does not have available ex-students now, and nor is that something that can be garnered "on the fly." Yet that is where the proof will come from in terms of measuring how well the PAC is doing. Hence, over a long period of time we should be devising a plan to survey former TRAC students, find out what they are doing, and query them as to the utility of the PAC.

- *Metric* units of measurement should be used throughout the PAC, as these are becoming an industry standard.

NEW MEXICO SCHOOLS

Southern New Mexico TRAC Volunteers

The interviews with facilitators focuses on two areas: (1) whether there are civil engineering or transportation components not covered by the modules and (2) identifying the salient features of the modules that teachers find useful. In this particular case, two TRAC Volunteers from the New Mexico State Highway and Transportation Department were interviewed together. Additionally, the District Engineer and the TRAC Director and Chief of Human Resources were present for part of the interview.

BACKGROUND INFORMATION

- The impetus for this state's program comes from the top down: the idea for New Mexico to use the PAC came from its current director 3-4 years ago and the district engineer attended the first national TRAC meeting.

- The District Engineer (one of six in the state) is supportive of the volunteers' work in terms of attendance at training, class preparation time, and obtaining extra supplies and equipment: they have access to DOT equipment when working with students. At least one, and sometimes both volunteers, visits the school on a weekly basis. The District Engineer is also an alumnus of this particular school.

- The volunteers have been with the program for the past two years; one of the volunteers was just given the "Outstanding Volunteer of the Year" award by the Alliance for Transportation Research, which funds a large portion of New Mexico's TRAC program.

- The volunteers want to get the word out to students that engineering can be "a fun job." More importantly, though, they want to broaden students' horizons so that they will consider going to college. This is a poor area, and many students who are perfectly capable of going to college do not do so because they never think of it as a possibility.

- A lot of students are from Mexico, and communication can be a barrier. Probably the school would not go for bilingual education, though.

- The state has been involved with the PAC for the past four years. These two volunteers have worked for at least two full years with the PAC, and have visited Biology (20 students), Chemistry (20 students), technology (up to 35 students), and physics (10 students) classes. The principal decided that they would begin using the PAC in the biology class. Since the biology teacher would not use the PAC, the volunteers have been the ones to do the experiments. (The interviewees mentioned that the teacher did not use the PAC because the teacher was not familiar with the subject matter).

- Teacher turnover contributes to the general problem of PACs not being used. One teacher mysteriously dropped out of the TRAC program and gave the PAC to another teacher that had not been approved. The current technology teacher, however, is extremely capable and takes on the PAC activities himself.

- *Funding* is a bit different in this state. The Department does not fund the actual PAC except through the contributions of staff time. The Alliance for Transportation Research (ATR) is a consortium of New Mexico State University, the University of New Mexico, Sandia National Labs, Los Alamos National Labs, and the New Mexico State Highway and Transportation Department, and this consortium contributes $26,000 annually to the TRAC program. This covers the $13,000 participation fee required by AASHTO, the purchase of PACs at $1300 to $1400 apiece (minus the computer), and some costs for teacher travel (or volunteer travel) to the training sites.

- Although *tracking of the former students* is hard, there is at least one case where one student who previously had not considered college ended up being influenced to attend because of an interest in the PAC.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

The volunteers felt that they had a good rapport with a group of students who seemed to excel with the hands-on activities. Ironically, the volunteers found out at the end of the year that these were the "D or F" students – yet they were motivated, intelligent, and asked good questions. Overall the volunteers noted three reasons for why the PAC activities are useful with this group of students:

- the activities are hands-on
- they can be related to theory, where one first does the activity and second one brings in concepts, and
- the students see how "fun" an activity can be
- they are excited to think they could actually do engineering activities, in large part because these were activities that captured the students' attention and could be done by all students at the same time.

As for specific PAC modules, three have been used:

- *Maglev* was by far the best module. Finding stores where you can buy the magnets, though, is tough to do.
- The *motion detectors* simply did not work, and the computer died as well.
- The *force probes* did not work well, but one can get around some of these problems. For example, one notes that the force reads negative instead of positive, so one can reverse the readings. Calibration also helps, which again takes time. At one point, calibration was not feasible because the software asked for filenames that were not on the PC.

Other modules have not been used:

- *SimCity*, for example, is a problem because one PC must be shared among all students.
- The *sound* module simply does not seem to be as interesting as the activities that use the force probes.
- *PC-Solve* has not been used yet but it will be attempted later.

Necessary Modifications to the PAC

During the course of the interview, the volunteers noted several additions that they made to the TRAC curriculum and materials, depending on the ability of the students. These include the following:

- *Answering the questions* that really interest students, such as
  --how much engineers make!
  --what the job is like, or what do you do?
  --do you get a company car?

- *Questioning the students* about how engineering relates to everyday life, such as
  --If you want to travel from here to there, how do you get there? Who fixes the potholes?
  --How did the water you used for your shower this morning get to your house?
  --What kind of stereo do you have? It is one of us "nerds" that make you guys "cool!"
  These questions force the students to realize that there are people who use these concepts to create useful products that the students then use.

- *Acquiring supplies*. Schools simply do not have the resources for this, so volunteers had to be creative for getting materials. This includes both having extra PACs from which one may cannibalize spare parts, purchasing materials (e.g. balloons) from nearby art supply stores with funds provided by the District, and using materials found at the office, such as electronic scale. A challenge to this is that it is then hard to distribute materials geographically to the schools.

- *Impact attenuators*. Simply using the force probe in the PAC lab doesn't really drive home the relationship between momentum fundamentals and transportation. Hence the volunteers tied this module back to something that is key to transportation: the design of impact attenuators. *First*, a promotional video was shown that had been sent by vendors; the volunteers noted that vendors provide samples of their equipment to a state DOT, and these samples can be used to supplement the PAC. *Second*, students used the force probe to design their own attenuator. *Finally*, they were asked "what would happen if this were a real crash?" In short, this is a way to relate the notion of force directly to key transportation concepts.

- *Spaghetti bridges* were created instead of using the bridge builder software. Weights were available from the chemistry classroom, and one could place heavier and heavier weights on the bridge until it fell. Incidentally, the volunteers were able to know what types of materials are (or are not) available in the classroom by being there; in this case, they could not figure out how to attach the probes to the bridge but one volunteer saw out of the corner of her eye the weights in the room.

- *Using the PAC at a different level*. For example, working with the AP physics students was not as rewarding – those students felt that they already knew the material as well as anything the volunteers could teach them, which was not the case. (The students also expected to get higher paying jobs than the volunteers when they get out of college.) Yet it was still possible to have them get a lot out of the PAC: one can show them a momentum formula and say "As a designer and engineer, you have to use and understand this equation. Figure it out!" Three of the AP physics students did end up going into engineering.

- *Competition* worked well; groups of girls and boys competed against one another, and the girls won, even though they originally did not think they were "smart enough" to do the activities. Additionally, the students competed against the volunteers, who were doing the activities as well.

- *Computer manipulations*: the volunteers had trouble with the PC not having the Windows operating system.

- *Team teaching* using two volunteers works well with students. They could teach alone, but it wouldn't work as well as the tag team approach.

- *Supplementing the manuals*: The volunteers felt that the lesson plans and instructor's manual were easy to follow and the equipment was relatively easy to set up. Yet the student's manual was more difficult for students to follow: the volunteers had to give out the information a little at a time and had to explain concepts to students a few times before they could to the activities.

IDEAS FOR FUTURE PAC MODULES

Several modifications should be made to the PAC.

- Add a *printer*, so that, for example, one can print the graph created with the force probe.

- Put *SimCity* on multiple PCs, for example, one class has about 20 computers spaced out over several workstations.

- *Cover transportation issues that differ in Mexico* from the U.S.: for instance, in terms of safety, guardrails are used differently because of different funding schemes.

Teacher from New Mexico School 1

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs. (The TRAC Director was present for this interview, along with one of the TRAC Volunteers).

- The classroom is a technology lab that was funded through a consortium of sources sought by the teacher. This is a 90 minute daily technology class, where students learn skills such as CADD (computer aided design and drafting), video production, robotics, interior design, and computer repair. Skills such as physics, math, graphic arts, and data testing and acquisition are all relevant.

- The technology lab is located in the old welding shop. There are six islands, one for each technological skill taught, 10 CADD computers, and plenty of space to move around.

- The class is open to 9th – 12th graders, but about 80% of the class are seniors who get priority assignment. There is a waiting list for the class. While 34 students are currently enrolled, the class can handle up to 40-45 students and still allow them to work in groups of two on the various projects. (The day of the interview, however, it appeared that there were no more than two students per station!)

- While the high school has had the PAC for about three years, this teacher has only had it for about three weeks. However, he has attended TRAC training with his volunteers. Already, though, TRAC is being integrated into the classroom as one of several stations; Maglev is the focus so far.

- There is a lecture portion the first week of class, but with 15-20 different subjects being explored by the students, the class consists of mostly hands-on activities. Occasionally, these will be supplemented with "service days" where commonly needed information such as logging off and on are explained to the whole class, as are common problems experienced by the class.

- Student help is a major component, and this shows student interest. For instance, one student has volunteered to help repair and upgrade computers in his spare time.

- The school is in a poor area and has 1200 students.

- Graphing calculators are used at this high school, but only in the higher math classes.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

Maglev: The Maglev module is currently being used as one station of the six available stations. One group of two students has chosen the Maglev activity as their "final project" even though it has only been in the technology classroom for a few weeks. The teacher likes the Maglev activity because it involves mathematics and problem solving and challenges students. The students also like the design aspect of the Maglev activity and the hands on building of their cars.

Instructor's Manual: The teacher felt that the PAC instructor's manual was clearly written and he liked the way it was put together. He planned to use it as a model for his technology class manual. Other lab manuals he has seen are less clear and often don't correspond with the software used in the labs. For instance, one manual has instructions for Adobe 4.0 when in fact the current version on the PC is 5.0. However, other lab manuals are tied to national, state, and local SOLs are the PAC manual is not.

According to the teacher, one good aspect of TRAC is that the students learned from the volunteers what a civil engineer does: it's not just math, it's not just operating a bulldozer, and it was shocking for the students to find out that math might only occupy 45 minutes out of a week of an engineer. It was also interesting, for example, for students to learn about the various zones of a traffic signal; there's more to it than simply a red/green/yellow light. At least one student who had wanted to be an architect changed his career choice to civil engineering.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

A *successful* activity is one that generates student interest, gives the student a reason for doing the activity, has a sense of closure, involves design, includes teaching, and encompasses open-ended questions:

- An *unsuccessful* activity, on the other hand, just keeps a student busy. As an illustration, consider one useless activity that has been done in the past: to learn how to a probe or sensor measures temperature, students watched the temperature rise as water was heated. The solution for making this experiment useful, in this case, would have been use probes to measure heart rates of males versus females or before versus after-exercising: in that way, the act of measurement could be learned but in the context of doing something useful rather than as an activity that occupies time.
- Students like to *design* cars, both by style (e.g. make a car look like a fish) and performance (e.g. see how the car performs on the test track). Whether one is adding vents to the car or using a different material, such as clay, it is the act of designing that is fun.

- The *final projects* give students a lot of flexibility: they are told to think of the whole semester and then pick something that encompasses what they have learned. The projects are interesting: one student is doing "the many hairs of Michelle" where presentation software skills are being gained by illustrating how one student's hair color has changed every year since the third grade.

- *Open ended* questions are helpful: students can follow instructions acceptably well, but what-if scenarios are better.

- Having students who understand a concept or a piece of equipment answer other students' questions reinforces learning.

- Finally, to encourage some writing on behalf of the students (since they tend to want to say things rather than write them) one tack is to have students *start small*, writing a couple of paragraphs before asking them to provide complete documentation. Also, this writing can be supplemented by other means of communication, such as video.

In general, the students like hands-on graphics and software, as well as the hands-on activities. (Note there is a distinction between hands-on activities that use the PC and those that do not require a computer). Students tend not to like documentation and writing, but the teacher notes that some writing is important. One good way to accomplish this was with the use of some time-line software, where students did a research paper on Lincoln.

The teacher also had some good ideas on how to teach, regardless of the materials that are used. Examples include the following:

- *Encouraging mistakes*. In the past, there were students who had never turned on a PC and were extremely shy. The teacher was able to work with them one-on-one, though, to encourage them to use the PC: they could get into trouble with the computer and learn that mistakes were not fatal. Note that a 90 minute class really affords this luxury.

- *Obtaining funding is critical*: this teacher went out on his own and got funding, for example, for the Internet line, getting 50% supplied by the bank and 50% supplied by the school in terms of the line. Later, the bank took on 100% of the funding. The teacher pays for the Internet service out of his own pocket.

- *Keeping materials updated is a challenge*. Flexibility is essential: for example, since different versions of AutoCAD (releases 10,11,12, and 13) are on different computers, the teacher uses this to show to students the value of upgrades to the software, starting everyone on the tougher earlier releases and then migrating them to the later releases as well. This lesson was driven home at the state competition, where one student (who knew both the older and newer versions) did well because the competition used an older version of the software. Another student, who knew only the newer version, did rather poorly.

- *Technical support* is critical; with Adobe, for example, the company's tech support went so far as to provide a conference call between the school, the computer company, and itself when it realized the problem was not necessarily with the software, and the teacher could not make an outgoing long-distance call. They also provide overnight equipment replacement.

- *Learning from students helps as well.* There is a sophomore student who does excellent work independently; he is so sharp that he almost "lives in the lab." The teacher has now asked the student to writes a journal of troubleshooting tips at each station, to which the teacher may refer. In addition to helping the teacher, though, the journal serves as an outlet for this very bright student. Additionally, this same student set up a messaging system for the entire class, downloading the appropriate software for the server.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

In order to get the school board to approve the new technology class, the teacher had to put together a set of SOLs and the lesson plans designed to meet them, including methods of instruction. The teacher felt that the SOLs are key, because there is no way of measuring student achievement without them. The idea in the technology class is to meet or exceed what 12^{th} graders are supposed to accomplish. Even though technology is a new subject area, there are national technology learning standards, on which he based his course at least in part. Local expectations may be found within the EPSS (Educational Plan for Student Success), where students are constantly challenged with math and problem solving.

It is not difficult to cover various SOLs in this 90 minute technology class, though – one can cover math, physics, biology, English, and history all within the context of the course. For instance, some students use time line software to track historical events.

IDEAS FOR FUTURE PAC MODULES

"It would be nice to tie in the various transportation scenarios to the Internet: as a teacher, I can then make them more advanced if necessary, but I need the subject material to change weekly or monthly. As a general rule, I like *choices*." Hence additional scenarios and applications for PAC activities could be created and made available via the Internet.

Students from New Mexico School 1

Five students in the technology class were interviewed; two students in a group that was using the PAC Maglev materials, then two other students who were focusing on a video project, and finally a former technology student. The students were asked what kinds of activities they like and don't like, and their oral responses are transcribed below.

Two students using the Maglev materials

Regarding specific PAC modules, *Maglev* has been used the most so far, since the two students are using it for their semester project. The students had tried two or three other modules that had not proven as interesting: students have already played *SimCity,* they skipped *PC-Solve,* and they had used the motion detector. They interpreted negative readings from the force probe by reversing the sign. In some activities, though, it was tough to understand what the graphs meant. Overall, though, it is fun to try new things, which is why new activities are selected in the first place. Something else that is fun is problem solving and improving on labs. For example, in one lab with flywheels, the students were able to show the teacher a new way of accomplishing the lab.

One student has an interest in architecture and civil engineering, and the use of the Maglev materials relates to this; both students like math as well. The day of the interview, they were trying to stop and start cars on a level surface; in the future the students are looking for ways to make a train out of two cars that are linked together. The use of a motor for a foam car has been considered as well, but the motor would have to be very light.

An unsuccessful activity involved pneumatics, where the students hooked up hoses to make a cylinder move; the activity took about a week. In that case, it would have been useful to give students some idea as to what to do first. Interestingly, these students felt that they could follow the TRAC student manual on their own.

These students also mentioned that they disliked writing, especially in light of the pneumatics labs, where they had to write two pages on what they had learned. They felt that essay questions would be less distasteful if they were allowed to include their own opinions.

Two students at the video Station

These two students are doing a project that entails the use of video and the Internet to produce a piece illustrating interactions among so-called "gang" members. The purpose of the piece is to show that people in gangs have a human side to them as well. The project involves interviewing people who are in a gang and asking them a series of questions, such as why they joined, what they do for fun, and where they hang out. Poetry from members will be collected as well, as some members find it easier to express themselves with poetry or song, and some use an Internet site as an outlet for their poetry. The students note that "gangs are a family of friends: a lot of members join because of peer pressure, and a lot are scared." The perspectives of these members, as well their future aspirations and video footage, will be collected into the project.

The students enjoy the pictures aspect of this project; they also noted that they liked the previous time-line project. While one student noted she was not fond of the wind tunnel lab done previously because it was too loud, the other noted "there is nothing that I don't like" in regards to the technology class activities.

Former technology student

This particular student took the technology class last year, which was very different: the lab had not yet been created, and there was only one PC for the entire class.

The student recalled designing and sanding a Styrofoam car, and recalled that this activity was meaningful because his car was different in *style* from the rest of the class (he built a convertible) and he also learned about how properties of the road and car affect *performance*. He also noted that it was much better because the activity was hands-on: unlike a computer or paper and pencil activity where you have to use your imagination, you can do actually build something, and most importantly, you put your own self into the design. Racing the cars was fun as well; although the magnets need to be straighter.

This student dislikes writing things and doing reports, and it is hard to convey one's enthusiasm on paper, unless the person who does the writing also presents his material. Thus a solution could be for persons who write material to then read or present it to their audience, varying their voice appropriately.

The student notes that he plans to study history in college, because it is important not to repeat the past. For example, with war, it may be able to be avoided by knowing the causes. Before going to college, though, he will work in his father's construction and landscaping business for a year. He also might like to start his own business.

Finally, the student mentioned an example with the "Dodge Ram Escapee." Both interviewers' notes were scant at this point, however, it may be the case that the student was linking the need for history to automobile design, in that one needs to understand how automobile designs have evolved over time in order to make automobiles better.

Principal from New Mexico School 1

This person has been the principal for seven years.

FACTORS DETERMINING WHETHER AN EDUCATIONAL ACTIVITY IS TO BE USED

Note that this school is rather isolated, so they do not get bombarded with ads for educational materials. As a rule, though, they have a committee composed of a guidance counselor, the central office instructional curriculum director, and the area curriculum director that makes decisions regarding what kinds of activities might be acquired. There are several areas that this committee considers:

- *Bilingual education*: it is definitely appropriate to teach English and Spanish side by side from first grade on up. They do not share the California notion of throwing everything out!

- *The economic community*: this is a poor community with many single parent households, and the principal wants to keep his students in school as much as possible, even though there is considerable pressure for students to quit school and go to work.

- *Help with testing*. The principal disagrees with the use of the ACT and the SAT standardized tests which favor white middle-class males and are note geared towards Hispanics or African-Americans. He notes the need to level the playing field with these tests.

Additionally, the principal feels that the school needs to educate students not just in general labor but in a specific skill. Right now, they teach students how to go to college but they should also teach them how to get a job. This means knowing what to wear, writing a résumé, and learning to sit down and focus during the interviews. The school also needs to develop skills such as welding, surveying, and auto mechanics! It's expensive to get automobile service in this area, because the area does not have the skilled personnel, and the school district can not obtain the $100,000 machine for the auto mechanic shop even though a lot of business comes from the nearby Interstate. (The TRAC director strongly agreed regarding the need for surveying skills. A module of the PAC could encompass surveying, GPS, and laser-based equipment; in short, the state agency recognizes a dire shortage of trained surveyors and the PAC could help meet this objective.)

Institutional Considerations

An activity could be rejected, of course, if it involved violence or sex.

The principal felt it was important to note that the students at this high school have great minds. They know if you are sincere or if you want to help or hurt them, and they're nice kids - not gangsters or thugs. The students when disciplined may even say "thank you" because they know you are helping them. If an educational aid is to be used, then the providers of the aid should prove that they understand this paragraph.

Also note that there is the potential for some coordination with New Mexico State University.

Finally, the TRAC director noted that as a state, New Mexico is very large but has a low population, resulting in it having less representation in Congress and thus getting less funding for education.

Teachers and Federal Programs Coordinator from New Mexico School 2

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs. The TRAC Director was present for this interview.

This school is situated on a Native American Reservation and is a “638 Self Determining Grant School” of about 345 students from all grades in a very isolated part of New Mexico. This is unique in several aspects, one being that the school population does not change: 90% of the kindergarten students will graduate from this same school. “Isolation” in this sense refers to both physical separation (phone service had been down all week prior to the day of the interview) and the fact that this reservation has little contact with the other Navajo reservations.

Because of the school's “self determination” status, the school's funds do not come to them through the Bureau of Indian Affairs (BIA) and thus, the local school board makes all key decisions concerning the curriculum and materials. The BIA is the federal agency charged with overseeing the workings of the Indian reservations in the United States, including the 182 Indian schools, which tend to be underfunded compared to other public schools. The BIA can be thought of as, a federal agency acting as though it were a state agency, i.e. maximizing the bureaucracy. The BIA also makes all policy concerning the education of Indian children, some of which is not always agreed upon by the educators teaching in the Indian schools or the reservation parents and residents. For instance, the BIA curriculum contains a whole section on gambling (including the mechanics of the games and idealized careers in the gambling industry), a topic that elicits mixed feelings within the Indian community. Through the school’s act of becoming independent, educators and citizens gained more control over their school’s programs and the important opportunity to apply for additional funding and soft monies, an opportunity denied BIA schools.

The fact that the Los Alamos Reservation is isolated from other Navajo tribes facilitates their getting grant monies. Two new preschool classes have just been funded with Head Start monies, and the school system is about the receive a $1.2 million grant for an alternate adult high school program. The Navajo School is also allowed to choose whether they will follow national standards of learning (SOLs), BIA SOLs, or New Mexico state SOLs; they are leaning toward state SOLs as implied above. The school is accredited just as other private schools in New Mexico are.

Although the TRAC PAC had been used in the Navajo School for several years, current use is minimal. The teacher who was assigned the PAC had been reluctant to share it with other teachers, outside of his wife, who was a second grade teacher at the school. (There was some curiosity as to how the PAC could be used in second grade classroom, but no one had any answers to that aspect.) Apparently, that teacher left the school under less than optimal circumstances and when one teacher went looking for the components of the PAC, several were missing, such as the MAGLEV equipment. (Once this was conveyed to the New Mexico TRAC Regional Office, they decided to send a whole new PAC within days of this interview.) Since the school is on a quad system, new classes will start after Christmas, and teachers plan to begin using TRAC more then.

Ray[*], a mathematics and physics teacher, has been teaching at the reservation school for about 7 years and had used TRAC about this time last year. The physical science and technology teacher, had just begun teaching at the school in September and hadn’t had a chance to use the product.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules’ strengths and weaknesses, including the utility of the instructor’s manual and the student’s guide.

[*] Not his real name.

Bridge Builder: Ray liked the Bridge Builder software so much he bought several more copies of the program himself so that he could have it on each of the four computers in his classroom, giving more than one student or group of students simultaneous access. He felt that a site license was needed. Although Navajo culture stresses group cooperation over individual achievement, his students enjoyed competing to see who could build the strongest bridge. He also used it extensively with different levels of students and classes. He noted that in order to get his students started with Bridge Builder, it took about 20 minutes of one-on-one instruction so they could see how they could improve on their designs. The analysis, design, and redesign of the bridge are the real meat of the program, even though the graphics might act as a “hook” to attract the students. Bridge Builder also presents the construction of the bridge and the consequences of poor design (i.e. the truck falls through the bridge) as a real world problem and not just a conceptual one, which works well with his students. The Navajo students need to be able to see the big picture in relation to their assignments. Doing an assignment just to do it lacks meaning for them, and doesn't work well.

Motion Module: Ray had used the motion module with his students, but felt that the sensors were difficult to calibrate. He spent a couple of hours getting the activity set up before the kids arrived for class. In fact, it had taken 3 or 4 people an hour to an hour and a half to get the probes working during the training course.

SimCity: Ray had also bought several more copies of this software for the computers in his classroom. The school does have a computer network, but the networked computers are very slow (some are IBM 286s). Students will sometimes stay after school to play SimCity.

Sound Module: The teachers had experimented with the sound sensors but hadn't as yet used them in the classroom. There seems to be a disconnect here between the manufacturer’s manual and the lesson plan as the PAC.

Force Module: The force probe was used mostly with the 9th graders and above. The Navajo students like hands on projects, the more practical the better, and so they liked this activity very much. (According to Ray, activities that involve writing, analysis, and figuring how things work exclusively in their heads were a turn off for these students.) The force probe was hard to calibrate, and calibration instructions were not included in the Instructors' Manual. Some basic instructions were found in separate documentation that came with the probe in the PAC; however, these instructions may or may not be sufficient, and in the future, one should have all the instructions together in one unit.

MAGLEV: The MAGLEV module was used by the previous TRAC teacher last year during the second quad. There was some indication that it was also used in the second grade class (although it may just have been stored there). One of the problems with the MAGLEV module is that the students have never seen a train of any kind.

PCSOLVE was extremely difficult for the math teacher to figure out and took too much time, so it was never used. The teacher did point out that it seems analogous to using a spreadsheet, however. More support for PCSolve is needed in the instructor’s guide as well.

Improvements for the Student’s Manual: The student guide included some good ideas for extensions of the TRAC activities. Overall, there are not any real problems with the student’s guide.

Improvements for the Instructor’s Manual: According to Ray, the lessons in the Instructor's Manual were pretty well written. However, he felt that it could include more on how to get the activities and equipment set up and how to troubleshoot the activities (i.e. “If this is what is happening, then this is the problem and this is what you do about it”). Specifically, all documentation concerning the equipment should be included in the manual so the teachers would have to go to **only one source** to answer all their questions. He felt that the manual assumed that the teachers would have at least one free class period to set up the equipment and another to use it in class, an assumption that may not always be appropriate.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

The Relationship between Cultural Differences and the Effectiveness of Instructional Aids

As mentioned previously, this set of students comes from a culture that is very different from the mainstream culture. The reservation is very poor, so there is considerable pressure to go to work after high school rather than attend college. Their community norms are extremely important, but sometimes conflict with the traditional goals of education. The students tend to be what the coordinator calls left-brained -- they need to see the big picture before being able to do the steps required in a task or lesson. (In fact, one of the teachers pointed out that an aspect of the PAC that he appreciates is the ability to obtain a graph very quickly from sensor output.) All lessons have to have a purpose. The students tend to be creative and artistic, but have trouble following written directions. They are less sequential or linear than other students. Their culture stresses group cooperation over calling attention to the individual, and some students may be shier about class participation or role playing. In the Navajo culture, 15-year olds do not look adults in the eye, much less question an adult. (This is a handicap in the working world as well as in school.) The students need structure in order for an activity or lesson to work -- if they don't have a pretty good idea where the teacher is going and what he or she is going to do, then the lesson may fail.

Another problem is that English, the language in which classes are taught, is almost always a second language. About 92% of students speak Navajo prior to English. Research has shown that if students don't have a good background in their first language, learning a second language may be more difficult. While the Navajo language has a strong oral tradition, there was no written Navajo language until the 1940s. Thus, some younger children may need work in the Navajo language before attempting English or a dual English/Navajo track may be needed in the early grades. Poor readers have trouble in science or mathematics not because they lack ability but because they can't read the lessons/instructions. Reading ability is getting better in the Navajo Community School, but is still a problem.

The language barrier is a complicating factor when it comes to acquiring suitable educational materials at the high school level. Certainly one can find ESL or mathematics curricula for 11th graders; the challenge, though is finding both in the same module. In this vein, one teacher felt that sometimes mathematics can be used to break down language barriers since math is more of a universal language. (In fact, on standardized tests the scores are usually higher in math than other subjects since math requires less English.) Modules may need customization beyond language, though: students will not necessarily understand a typical “curb and gutter” design problem because that is not found on the reservation, so activities need to be structured in such a way that they make sense in the environment in which they are taught.

Communication between teachers and Navajo families is also sometimes a problem. Of the 1,200 households on the reservation, only about 400 have telephones. Some have no electricity or running water. Thus, teachers have to send notes home with children or go to their homes, and many families will not come to school when asked. Ray mentioned that the reason he was accepted by so many children was that he participated with them in outside activities as part of the Outdoor Club.

Finally, two examples were given to illustrate the differences between the Navajo students and their mainstream counterparts. In a biology class, in order to get slides of various internal organs, the class butchered a sheep. They then harvested the organs. The activity was followed by a community meal, which is in keeping with the culture. In the second example, a very bright senior was advised by his teachers to begin filling out college applications in the fall of one year for entry into college in the fall of the next year. He went home to ask his grandmother what she thought he should do. Her response was that she thought it might be bad luck to plan so far in advance. The home and school cultures conceive of time in different ways in the Navajo culture, one only plans for the next day or two. By the same token, one never takes more than one needs for the present, since that would entail taking away from someone else (e.g. one would not chop a week's worth of wood at once). Finally, learning is perceived in Navajo culture as a continuing activity. Milestones like graduation may have less meaning.

What works well?

Hands on projects that have a finite and clear objective tend to work best with this student group. For instance, the middle school students built rockets in the technology rotation through career clusters. They built the rockets, launched them, and calculated the altitude and attitude of their launches. This activity excited almost all the students, as did the a similar activity where cars were designed. The students also built bridges with Legos or used motors to move Lego structures. DATACO provided the equipment for this with the school supplying only batteries. The students really enjoyed these activities, because they could really relate to what they were building (cars, cameras, things they had seen on TV).

Another activity that works well is an exercise in which the students grow tomatoes. The school has a greenhouse, and each year students raise tomatoes, determining the best agricultural methods and collecting scientific data on their results, assessing the cost of the endeavor, and setting prices to make a profit. They then design a marketing scheme for their products, do the inventory, and finally sell their product. This augments family incomes and is also a valuable lesson. About 100 out of the 345 students also participate in 4-H, raising livestock for competitions.

Another type of activity that works with the Navajo Community School involves getting the kids out and doing something real, like the field trip to the warm spring and a river project. In terms of measurement, having them use a traditional way of measurement and then a scientific method and comparing the two works well. For instance, having them pace off 100 feet and then measuring 100 feet validates the scientific method. Another strategy that works with the Navajo students is to work toward the same point in different classes, providing integration on a topic.

Incidentally, the Internet has been a boon, because it is text-based and interests the students: they have to read in order to get at the content or emails that fascinate them.

Finally, the Science Olympiad worked well with these students. The work is team oriented, stressing cooperation, involves many activities, and let's them see the fruits of their labors. Activities include an egg drop, tower building, paper plane aeronautics, CO_2 rockets, tennis ball launching. entomology, compass courses, and more. The students love teamwork and solving problems in teams.

What doesn't work?

Although the administration wanted to have a TRAC volunteer involved in their program, the previous TRAC instructor did not want to become involved in this way. The teachers felt that the program would have worked better if they had had free access to the equipment and if they had had a volunteer. (Again, the New Mexico Regional Office promised to have a volunteer visit the school very soon.)

Also, experiments or equipment that doesn't work loses the students' interest. Ray felt that they needed an immediate source of outside help if equipment didn't work. The TRAC director supplied him with the TRAC 800 number, which should cover most of the school day.

Finally, the students need structure in their activities. They like to know where they are going and what they are doing in the particular lesson. For example, the interviewers had met with the students previously and asked them to describe activities they liked (and did not like) and how they could relate to mathematics. The teachers pointed out that one of the problems with this sort of work is that the students needed a more firm grasp on what is being expected of them; the assignment was probably too intangible for their taste.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

The Navajo School is so isolated that the teachers are often free to interpret the standards in their own way, rather than be tightly tied to a structured curriculum. As far as the teachers are concerned, they are focusing on developing students' basic skills and understanding what motivates them. The coordinator deals with the SOLs and the paperwork having to do with meeting requirements, leaving the teachers free to focus on the needs of their students. As far as she is concerned, the school is looking for motivational activities. If one can fit an activity into the state standards, that is great, but it is more important to have activities that work with their students.

IDEAS FOR FUTURE PAC MODULES

The teachers recommended both improvements to the current PAC as well as lessons that could become new PAC modules. These are listed here:

- The TRAC Computer needs to be *portable*, so that it can be easily moved from classroom to classroom.

- *Cost calculations should be added to the Bridge Builder* so that the project would be better tied into the real world. This work with cost, in fact, could be a substantive activity in itself. One could expand cost to other transportation activities, such as gas mileage or the benefits of aerodynamic design.
- *Auto safety* should be included in TRAC. Drunk driving is a serious auto safety problem in the Indian community and would be both interesting and instructive to the students. One of the instructors had a copy of the pilot test edition of an auto safety manual designed by Piel, Haight, and Williams at Penn State. This manual included traffic safety information but no activities. Motor vehicle collisions could also be introduced into other modules.

- The mathematics teacher has been forced to use TRAC activities as demonstrations because only one set of equipment comes in the TRACPAC. *More copies of the equipment* are needed so that several groups can work on the modules at once.

- An *environmental module* needs to be included in TRAC. This school has had speakers from the Water Environmental Resource Center (WERC) from New Mexico State University, discussing topics like how to cap a landfill. Environmental issues are not only important to the community but also part of their culture.

Students from New Mexico School 2

The interviewer began by placing the students in a circle and asking the eleven students which classroom activities they liked best. These are their oral comments. The students were 9th, 10th, and 11th graders in an Algebra I class.

One student mentioned the Algeblaster, a computer program including math problems and graphing. Another mentioned Number Munchers, a math program almost like Pacman. Even more popular was a Bingo game that used the results of math problems to fill spaces on a Bingo card.

When Bridge Builder was mentioned several students noted that they thought it was too hard, and it aggravated them when the truck fell into the water. One said that it was too hard to figure out why his bridge didn't work. However, another student really liked Bridge Builder, saying it was fun to try to make a bridge with the lowest kips. (Another student called him a nerd at this point, and he responded that you have to know how to use the program to like it.)

Most of the students thought SimCity was "pretty cool". They would begin building a city and were given a dollar amount that they couldn't exceed for services. They liked seeing the city blowing up, as when the tornado hit. Several felt that SimCity was more modern than Bridge Builder because of its better, 3-D graphics. Bridge Builder was more old fashioned.

One student had been asked to be a note taker during this time, recording what the students said. Her transcript of what the students said is given as follows, and is written without any editing.

What do you think about Bridge Builder?
  It is to hard, it makes you think to much.
  It is a great program.

What did you think about SimCity?
  You start to build a city. They give you an amount of money on how much to spend on the city.
  Blowing up stuff.

  What do you think about number munchers?"

The interviewer than asked the students to work in groups and determine their favorite activity and their least favorite, and why. Once this was done, he asked them to tie their favorite activities into mathematics. The students wrote their notes on the board and presented them to the class. The results were:

Least Favorite Activity	**Why**
Oral Presentations	Too nervous (less nervous in smaller groups or with friends
Reading	
Homework	They should have free time when they are at home
Classwork	Too much can make you lose your mind

Favorite Activity	**Tie into mathematics**
Basketball	You score points, do averages, calculate scores by quarters
Bingo	Involves problems and solutions, plus you can win money
Dancing	Steps involve timing, some slow and some fast. You have to change to the beat. (They liked dancing because you did it in front of other people.)
Internet	Learn from it, build new skills, look at other things in other places (good stuff)

Federal Programs Coordinator from New Mexico School 2

The coordinator is the vice principal of Alamos Navajo Community School. The principal was ill the day of our visit, but he and the coordinator work closely together. The purpose of the interviews with principals is to identify generally the factors that affect whether or not an educational aid, such as the TRAC PAC, will be used by the school. Hence the principal is able to offer insight from an administrative angle. The TRAC Director was present for this interview.

FACTORS DETERMINING WHETHER AN EDUCATIONAL ACTIVITY IS TO BE USED

The coordinator listed the following considerations in supporting a new educational program at the school.

- *Cost*: As is the case with most schools, funding is limited at the school. Only most cost effective programs can be purchased.

- *Endorsements*: Program information that comes in the form of a direct mailing is thrown out. She needs to have the idea for the program originate with the teachers or members of the board. In these cases, the school board is supportive of their requests.

- *Training and Support Services*: Training needs to be an integral part of any new program, and support services have to be available on a 24 hour a day basis. Teachers need immediate solutions to their problems with a curriculum or instructional aid, or it won't fly with the students.

- *Teacher Friendly*: Teachers need to be able to pick up the program and run with it. Extended preparation periods are unacceptable.

- *Curriculum Integration*: The new program needs to have a clear place in the current curriculum. Programs that meet multiple objectives are the ones with the best chance of implementation.

- *Assessment*: New programs need several levels of assessment. First, teachers need to be able to assess both whether students are ready for the program and whether the instruction will meet their needs. Second, an assessment of student performance must be included in the program. The Navajo School is moving toward a portfolio type report card, detailing what the students have accomplished during that grading period. Quantitative assessments could entail looking at the test scores to identify what students need.

- *Timing*: The program has to fit into their schedule. Flexible programs, those that can fit into both 50 and 90 minute blocks are the most useful.

- *Language*: Programs need to take into consideration that English is a second language for their students. Also, the language must be tailored to students of normal ability and should not be overly technical. (One exercise that the coordinator uses with new teachers is to have them select the textbook they want to use, and then have several students read through it underlining all the words they don't understand.) It’s important to define technical terms, provide a glossary, and not let the terms get in the way of the lesson.

- *Approach*: The programs need to encourages group cooperation.

Also, materials for any program chosen for use at the Navajo Community School must be of the highest quality.

There is no product that overcomes cultural differences on the market, however: that is something the teachers must be able to handle in the classroom.

INSTITUTIONAL CONSIDERATIONS

The most influential consideration is whether new curriculums or aids will work with their unique student population. Hands on materials where activities illustrate ideas and stress group learning tend to work best with their students. Some programs that have been successful include:

(1) Bottle biology: One of their licensed agricultural teachers used a program in which ecosystems created in 3 liter soda bottles illustrated biological concepts,

(2) The bottle rocket competition previously described,

(3) The Lego project previously described,

(4) IBM Writing to Read and Writing to Write: all of the IBM products were very good,

(5) The CORD Curriculum for Applied Mathematics: This program used laboratory activities for each of the career strands covered at the school. Students choose careers of interest early on, and each CORD activity tied the concepts taught into the career strand.

(6) Other CORD products, such as Applied Biology, Applied Academics, and Principals of Technology (although the latter is very expensive).

Central New Mexico TRAC Volunteers

The interviews with facilitators focuses on two areas: (1) whether there are civil engineering or transportation components not covered by the modules and (2) identifying the salient features of the modules that teachers find useful. In this particular case, two TRAC Volunteers from the New Mexico State Highway and Transportation Department were interviewed together.

BACKGROUND INFORMATION

- This is the third school year for both interviewees. One volunteer has visited his school only once since being promoted to a position of more responsibility. The other volunteer, who is also a "volunteer supervisor", has been in the classroom for the yellow light problem and the sound module, tying the activities into her engineering experience. There are two volunteer supervisors in the entire Department; each supervises volunteers in three of the six highway districts. The interviewees were originally recruited by the Department's Director of operations to train and organize the volunteers. Each district has three to six volunteers, who are normally recruited through a resident engineer.

- Although two volunteers are assigned per school, the frequency of volunteer visits varies: in one case, the school wanted one volunteer per week, while at the other extreme, there was a case where the volunteer went once during the school year. One middle school never requested a visit. On average, though, each volunteer might visit a school three times per year.

- The format of the visits may vary: one volunteer noted that for his first visit, he talked about general civil/transportation engineering – e.g. the role of striping, what the trucks do, etc. At the second visit, he let the teacher do the PAC activity (motion detector) but he was available. On other occasions, though, teachers view the volunteer's visit as a free day and expect the volunteer to do the activity.

- The volunteers noted, however, that it should be the teacher who explains the modules rather than the volunteers.

- The training has been well attended both by volunteers and teachers.

- The *mission* of the PAC in this state is to get more students and more minorities excited about math and science, especially the broader applications, and to advertise engineering as an attractive career option. (Engineers are not nerds with Ph.D.s who work alone in a room all day).

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

The *yellow light* problem failed massively for two reasons: first, the teacher had not tied the module to what the students were already doing in class and second, students did not understand the "yellow zone" problem. Also, it took the volunteer 2-3 hours to prepare this activity. In fact, though, every time the volunteer sees this problem he acknowledges it is complex, even with his engineering background. The volunteers noted that they thought the training from TRAC headquarters on this topic was well done, and in that case the trainer probably had done the module "200 times" before hand. The second problem could be resolved with a narrative or video explanation of the yellow light problem and its objective, showing, for example, the light as green and then turning yellow as the car approaches the intersection. The first problem could be resolved by tying the yellow light problem to math (and hence the students' curricula) as well as the concepts of acceleration and velocity.

The *ITS module* is weak: once students read the text, the activity is done in five minutes, and the teachers know that they will never use it. It fails in part because it is too simple and in part because it has no graphics. Improvements could be to have a real-life street network, coordinated signals, ramp metering, and a real life situation such as an accident in a construction zone. In short, make it more life-like, using software from an operations center at a Traffic Management System (TMS).

In general, teachers seem to like *Maglev* (as it is very hands on) and the *force probe*, although they have some questions about it. The volunteer explained that the *motion* module is not popular and that the detectors' range is so broad that multiple stimuli rather than only the target stimuli are picked up, producing a lot of scatter data. *SimCity* is also popular with teachers; students like the graphics, similarities to a video game, and the idea of trying to keep the city going without going broke. However, one volunteer was not sure how it could tie into a teachers' lesson plan unless it is used as a reward or to augment what the volunteer says about roadway design and placement. The volunteers speculate that in the future, *Bridge Builder* will become popular, especially because of the computer graphics and animation. They also recalled the demonstration of a useful sound module with a boom box and sine/cosine waves as part of the TRAC headquarters training. Finally, they did recall one volunteer who used the *social studies/town meeting* successfully, although placing the students in groups (e.g. an engineering team rather than a single person) was necessary.

Note, though that it is tough to determine usage because teachers tend not to send back the usage reports. There aren't any easy ways to increase the teacher response rate except to diligently follow through with the requests. Also, state awards for the "best volunteer" and "best teacher" based on the usage reports and volunteers' opinions may increase a response rate. (When a volunteer goes to take away the PAC because of nonuse by a school, the teacher will tend to promise at that time that he or she will use the PAC in the future.)

Finally, there isn't much in the PAC that can be used with varying abilities, especially in the middle schools. More needs to be added to the PAC to sustain the advanced students as well. The potential of the PAC is that it may help students who don't like math visualize the theories covered in the PAC.

IDEAS FOR FUTURE PAC MODULES

Several additional PAC modules were suggested:

- *Snow crew allocation*. It is actually quite a challenging problem when figuring out how to use crews for snow removal. One has to consider weather prediction, the fact that one wants what is good for one's employees, the fact that one wants to use employees in the most effective manner possible, and union rules, such as the required number of hours of rest between shifts. The maintenance engineer noted that depending one what he decides, he could place crew members on standby (giving them overtime pay without work), assign them jobs to do now but asking them to also be ready to work later (giving them overtime pay with overtime work), or send them home without pay (no pay but no work). It is tough to know what to do, especially when complexities such as inaccurate weather prediction come into play.

- On the same topic, there are also problems with determining *what should go into deicing chemicals*, after one accounts for salt content, variations in salt types, dew point, and barometric pressure.

- *Geometric design* (e.g. intersections or interchanges)

- *Software for managing an ITS [multimodal] center*: manage ships at a harbor, trains on a track, and a port facility simultaneously. This is not far fetched: one idea would be to use demonstration or software that consultants actually use for selling their products. In this case, the volunteer recalled an AASHTO presentation of ITS/port facility software that might be suitable for inclusion in the PAC. The software, of course, was originally designed not as a high school educational aid but instead as a product for use in the real world.

Additionally, several improvements to the existing PAC modules were suggested:

- *Add a narrative* to each set of activities. For example, in the motion fundamentals module, the narrative would talk about motion in the real world. Teachers want to know how they should use this material in the classroom. The volunteers believe that all aspects of their jobs eventually relate back to the PAC, but they need to be spelled out; for example, explicitly state the role of guardrail in the absorption of crash impact in the module on force and acceleration.

- Have a *double reference of SOLs* (standards of learning). Not only should each module cite the SOLs it covers, but one should also list the SOLs along with each module that serves the SOL.

- *Make the PAC more digestible*. Seeing the PAC at first is overwhelming: one could reduce the number of activities and make them better. One can also improve the instructions: perhaps simply state the objectives and replace the directions with video, since instructions tend not to be read (just like when you put together an item at home; you look at the picture and try to figure things out from there).

- *Train the trainers*. Most states cannot afford to have Tate [the trainer from TRAC headquarters] do a training session every time they have new people, but maybe something that would show these volunteers how to train other volunteers would be helpful. Additional training time is needed to fully explain the activities and to allow participants to actually do activities.

- *Explain what is expected of volunteers.* The volunteers noted that they believe some people are simply more capable in the classroom than others. When asked, though, they did offer some tips for first-time volunteers:

  --Be prepared to “wing it” quite often. Have a goal in mind, but realize that you probably don’t know yet how you will get there. Be prepared for anything!
  --Be relaxed.
  --Be honest. You don’t have to know everything about every topic – that’s what the teacher is for! You can always refer kids’ questions to teachers.
  --Keep the students involved as much as possible.

- *Make the manuals more readable*. The double column format of the instructor’s manual makes it hard to follow, increasing the amount of time teachers have to invest in preparing for an activity. Perhaps instructions could come in narrative or video form. Also, inclusion of sample computer screens for software products would be helpful, as would more pictures of equipment setups. The objectives of the activity should be listed at the very beginning.

Teachers from New Mexico School 3

Three teachers were initially interviewed together, also, one central New Mexico volunteer was present for part of the interview. After both this meeting and the meeting with the students, one teacher provided additional comments.

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs.

- This is a magnet school, where students come from 11 “base” high schools for part of a day to take diverse courses not already available at their home schools. Thus, they graduate from other schools and use the career enrichment center as a resource for classes in robotics, cosmetology, engineering, etc. This magnet school runs on a block schedule, with classes running for 2 – 2.5 hours at a time.

- This school offers other programs to students, such as activities with Kirkland Air Force Labs and the S.P.A.C.E. (Students Producing And Conducting Experiments) program.

- Partnerships with private industry are also effective: while companies such as Intel, 3Com, and Allied Signal do provide funding for some programs and equipment, the teachers point out that there is more of an emphasis on talking to companies, learning what skills their future employees will need, and then bringing these skills into the classroom. These partnerships are also excellent for keeping materials and curricula updated – they take time, but have some extra benefits, such as now the community college and high school are coordinating programs such that high school students can get college credits in some instances.

- One teacher who had taught in a regular high school for 13 years prior to coming to the magnet school taught a robotics class (this class of 12 students was later interviewed). Another teacher taught a C++ class of 6 college bound students. He had taught on the middle school level prior to coming to the magnet school and had just begun using TRAC the previous Fall. Another teachers taught a pre-engineering class of 10th through 12th graders and had been using TRAC for several years, having been through the first TRAC training class in New Mexico.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules’ strengths and weaknesses, including the utility of the instructor’s manual and the student’s guide.

The teachers noted that the only way they were able to use the PAC materials was because they were all working together. A regular high school would be further hindered in that getting the extra materials (paints, brushes, knives) is hard, and 50 minute blocks are too short for many of the modules. Additionally, they noted several aspects of the specific PAC modules:

- The *manuals* require some supplemental information, as well as extra work (e.g. “go find page x in some other source and Xerox it.” Teachers need everything to be in one place, so that they can simply do one set of photocopying and be done with it.

- The *yellow light problem* needs substantial revision. Fortunately, the computer science teacher’s six-student C++ class has taken this on as one of their projects: they are currently redoing the graphical representation and the intersection design, and they hope to be soon have an improved version out.

- In the *Maglev* module, assembling the track was difficult, because it came in pieces that did not fit together easily, creating breaks in the track. To solve this problem, the teachers are working on a new design that involves rigid PVC pipe or two-liter soda bottles, which would be easier to align the track sections. Of course, the cars would be designed differently, since the tracks would be pushing "in" towards a center rather than just "up" as is the case with flat track. [*this in part is the interviewer's interpretation*.] In any case, the track needs to be sturdy so that it can't be misaligned when someone bumps the table, it needs to be easy to fix, and the pieces need to be stronger (right now they break too easily). Overall, though, the teachers like the creative aspects of the Maglev activity, in addition to its technical aspects.

- *PC-Solve* has lots of power but is not user friendly; today students need to learn MS-Office applications, C++, Visual C, etc. Graphics were attempted with PC-Solve in conjunction with some other activities, but PC-Solve is simply not that useful: the Windows-based MS Excel graphics are far superior.

- *Bridge builder* is great, but the teachers need a networked version. At least one teacher uses it as a lab and for students who suggested it should be used within a competition.

- The *force probe* was too sensitive, but a simple call to Vernier showed that turning the screw solved the calibration problem. Unfortunately, this is not mentioned in the manuals nor in the training, but it should be. There should also be time during training to play with the probes.

- The *motion detector* is a bit complicated in that it is not accurate at distances of less than half a meter yet it has a 20 degree field of view, allowing it to pick up extraneous motion – this lab requires a lot of space or limits the scope of activities for which it can be used. [One teacher later indicated that he thought they could a robot to smooth out the graphs, and they will try this later in the spring.]

- The *sound module* has not been used. One teacher noted, however, that he does use Vernier software and equipment to measure sound electronically; he also notes that a lot of Vernier equipment is available.

- *SimCity* needs to be redesigned as an application because it takes so long for the software to react to a set of decisions, and it takes 50 minutes just to get up and running. Part of the city should already be built, since teachers are short for time, plus, one often has to transport students to a computer lab which takes additional time. (While there are pre-written scenarios for SimCity, some new ones should be devised specifically for transportation issues.) *Assessment is also important,* and how do you assess a student's achievement with SimCity? For example, one way to do this would be set a specific goal: as a city gets larger, it gets to a problem more quickly, such as crime. Make the students figure out, though, that crime is increasing because of a police strike, which in turn results from the budget being insufficient. Students should not be set loose to do SimCity but should be guided to use it for problem solving. SimFarm and SimAnt are also great problem solving packages.

- *ITS is weak*, but the concept is easy. Maybe graphics would improve that module.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

The *teachers listed several characteristics of activities that are tend to be successful:*

1. *problem-solving* is a part of it
2. *creativity* is encouraged
3. one can *build* what one is designing
4. one can *test* what is being built (e.g. racing a car)

5. there is some *secret* to it. For example, in the case of water bottle rockets, the teacher includes a balloon in the nose of his rocket but does not tell the class. While designing and launching their rockets, they are naturally curious as to why his goes farther.
6. there is a *challenge* to the activity.
7. *competition* is in one form or another, but one teacher later noted that competition is in varying categories: some students are competitive in the hands-on events (e.g. want the car with the best design) and others want to have the highest test scores. Often, though, students will be supportive of each other.
8. there is *more than one right answer*.
9. the activity involves a wide variety of *objects that the students don't often get to use* [but somehow the teacher can obtain these].

The teachers also described specific types of activities that they have employed that work well. While these activities tend to be time consuming, the use of block schedules and the fact that this "magnet" school is not as tied to standards of learning as the base schools (from which the students will receive their diploma) make these activities more feasible.

- *Motorized cars*. A D.C. motor was attached to a propeller which moved cars.

- *Sandwich bags of materials* are given to students to solve various types of problems. Interestingly, about 75% of the time the middle school students do better than the high school students because the former are not set in their ways yet and are still at an age where they can question everything.

- *Remote controlled cars* with magnets are used to pick up washers.

- *Water bottle rockets*, where the students used water and compressed air to see whose rockets went the straightest and whose went the longest. While the school could not measure height directly, they were able to use transits obtained from the trades department for this. Scale drawings of the rockets made them more useful.

- *Sine wave example*: another way example that was later mentioned regarding an activity that does a good job of explaining the meaning of sine waves is to amplify a sound wave so that its frequency and amplitude can be seen on a oscilloscope. Tuning forks are helpful in this regard; alternatively one can use a pendulum and motion detector.

Characteristics of activities that don't work include the following:

- *Pencil and paper*, although some of this will be necessary because ultimately any hands-on activity will require some linkage back to what standards of learning students need to meet. "Book work" fits in this category as well. One teacher pointed out that "there is no comparison to touching it, feeling it, seeing it and making it work."

- *Inconsistency*, especially if rules are not well defined. One needs to try and foresee problems before they arise; for example, in the case of the Maglev car races, the judges needed to resolve how to account for performance in terms of distance and performance in terms of speed.

- Activities or equipment *that do not work*.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

To be blunt, there are standards of learning that are important, but the PAC does not tie in directly with these SOLs. On the other hand, the PAC is material that students can relate to. This school is fortunate in that many of these classes are electives; hence, it is the base school that is responsible for meeting the SOLs while this school can concentrate on doing more useful (and fun!) work.

One of the teachers pointed out that even though his class focuses on pre-engineering electronics, he likes to ask the students what type of engineering on which they would like more information (mechanical, electrical, manufacturing, and civil.) The PAC, in his view, helps describe what civil engineers might do: for example, students now start talking about dual left turn lanes in class. More importantly, though, the teacher points out that engineers need to be able to work together; high-tech companies such as Intel want their employees to be able to coordinate with one another. Also, the SOLs could be related to the skills needed for civil engineering.

Finally, since middle schools don't have to worry about SOLs as much, introduce TRAC at that level.

IDEAS FOR FUTURE PAC MODULES

Several improvements could be made to the PAC, and there are some new modules that could be added as well. These include the following:

- *Provide a parts list*. Supplies such as Exacto knives are needed for some of the modules. The parts list could show what materials will tend to be used up and what ones can be used over and over again. Since it often takes 3 weeks to get authorization to spend $10, a teacher might be given a very small budget – e.g. $300 per year up front – for all textbooks and supplies.

- Suggest contacting *individual vendors directly* for technical support. A call to Vernier resolved the calibration problem with the force probes immediately.

- Consider the other *Vernier products*, especially the calculator-based labs, which are becoming more and more the norm: they are student proof, durable, and easy to use. There are clearinghouses available that describe all sorts of various types of hands on activities.

- On a related note to the above, consider a *Website* with descriptions of what teachers have already accomplished that works in the classroom – a sort of TRAC clearinghouse. It would really be nice if from an administrative angle, one could allow teachers the time to do this type of exploration. The teachers also agreed with the interviewers' suggestion that some type of gift (e.g. a free laser pointer) could be a good incentive for teachers to provide lesson plans or other useful feedback. They would also nominate and later vote for the lesson plan of the year.

- *SimCity scenarios could be developed* and structured so that students could learn some actual transportation concepts, including ITS. One scenario could be "where do you put a roadway given existing infrastructure?" [similar to the 2 dimensional design problem presented by Carlton Flowers at the 3rd Annual TRAC conference]. SimCity also somehow needs to account for how much traffic one lane can accommodate realistically.

- *Have a video in the PAC be about what civil engineers do,* not about the PAC itself. Let's describe, in 30 minutes or less, what a civil engineer does. Many who are qualified never go into the field, thinking that they can't get past the math. Consider as an example, the videos produced by the C.O.R.D. program in Waco, Texas, such as the "History and Advance of Technology."

- *Place the PAC on a cart,* which will help share it among teachers.

- Add a *role play activity*, where, for example, students assess the impact of a bridge across a residential area. This would teach them how to work in groups and how to solve problems, while grabbing their attention with local issues. For example, in the Albuquerque area, there is a new I-25/I-40 interchange being designed which must accommodate 20 to 30 year traffic forecasts. There should be both urban and rural role-playing scenarios. Drawings, plans, animations, and scenarios specific to this interchange could be a part of the PAC.

- One could also include other *transportation issues*: the design of computer, electrical, and plumbing systems or soil design.

- Teachers get tired of donating their free time to every new program. Hence TRAC should try to find a way for teachers to be compensated for their donated time (e.g. some kind of stipend.)

- The teacher also mentioned a “King of the Hill” robot competition that quite was a success; it mimics what MIT has done in the past, and the students enjoy the hands-on aspects of the project. The following semester, the teacher noted the use of “Lego Mindstorms” which the students also liked.

Finally, it is best if the volunteer can come when an activity is done. Teachers expect this volunteer to have a dynamic presentation that will interest the class and keep the kids on the edge of their seats, and the volunteer is also expected to come when he or she indicates they will come. By contrast, the teachers recalled an instance where a banker had promised to come several times and cancelled at the last minute. It would also be nice if the volunteer could come prepared to judge or grade a contestants in competitive events.

Students from New Mexico School 3

EXPERIENCES WITH TRAC PAC MATERIALS

The robotics students had some experience with some of the PAC materials, especially the video, the Maglev track, and the motion fundamentals module. While the Maglev track was a big hit, the motion fundamentals was a failure. Here's why.

The **Maglev** module is hands-on, especially the way it was done in this robotics class, where students designed their own cars from scratch and could follow the design process from beginning to end, culminating in racing their cars and competing for both distance and speed. They noted that you put yourself into this; you know what should happen, and when things don't work, you have a chance to figure out why. With trial-and-error situations such as this, the students note that the competitive atmosphere is contagious: even for those who are shy, all it takes is for one student to begin to succeed – in this case, building a car that moves along the track – and then everyone else wants to beat him or her. The students had some difficulty relating the Maglev activity to the real world until a father of one of the students brought in some information on Maglev trains. [The teacher felt strongly that the video on Maglev train in actual operation should work with the activity.]

The **force probe** worked about half the time and the car had to hit it just right to make it work. When it didn't work, about half the students lost interest. Of course, they (and the teacher) were just playing with the probe and hadn't read the manual.

The students liked **Bridge Builder** but had some suggestions. Since it is difficult to connect bridge elements in the middle of the bridge, there should be more ways connect them to the bridge piers at the end. [It was also thought that the students made mention of wanting to be able to have the bridge connect at different points along the shore, but this could not be confirmed.] Also, they wanted more types of bridges, including suspension bridges. They suggested adding explosive sounds and having the falling truck hit the boats as it fell.

By contrast with the Maglev module, the **motion fundamentals** module has you starting not at the beginning but in the middle. When, for example, motion is not detected, one then simply asks "why?" but one does not know where to start troubleshooting. A couple of students did, however, attempt some computer calibration of the probes.

HOW TO IMPROVE PAC MODULES

Overall, the students felt that the activities (and the manuals) would be improved by the inclusion of more visual aids or schematics. They liked designing, but thought that activities could be based on giving them a starting point and then letting them improve upon the design. There was some disagreement as to when additional information would be useful in a design problem like Maglev. Some students felt that "knowing what works" would have been useful before beginning an activity, some felt it would be useful after their first few tries, and some after they had completed the activity. Most seemed to feel that by waiting to provide more information until later helped students not to be tied into one design and challenged them to be more creative and trained "the mind" in problem solving. Their solution to the problem that some people didn't like the problem solving phase of the work was to encourage them. They felt that in every activity, there was one person who "got it" and could help and encourage everyone else, giving them tips. Being wrong in terms of their designs shouldn't bother anyone, since even the original designers of great things didn't get it right the first time. They thought that they should just try any "goofy" design and then see how it worked. Most felt that learning the facts about the concepts underlying activity at the beginning didn't help them learn, but providing this information in the midst of the activity might help. They also wanted to know what they could do with an idea -- what the applications were, especially if there was a potential for making money. This was something else they wanted to know about engineering -- What degrees would get them what starting salaries and what skills would the employers of engineers be looking for?

OTHER INSTRUCTIONAL AIDS

These students also brought up other educational activities besides the PAC that they had used in the past. Three examples were given.

The **sound** sensor in the PAC worked “okay”, but at least one student thought that the software was off. Alternately, they had done a sound lab with the CBLs. They had also done a lab where they played **human robots**. They started at one end of the school and their goal was to go to a central point. However, they had to write “software” or a set of rules that they were required to follow, prior to beginning the activity and then apply the rules based on data possibly from ultrasonic sensors. According to the teacher, most were extremely frustrated by the fact that their rules often had them going the wrong way, and wanted to break the rules. The teacher then reminded them that real software running robotics couldn't selectively break the rules to accomplish an objective**.**

Pneumatic arm lab: The students built a pneumatic arm using a syringe to target the water. The problem was that they had to make the arm move at an angle, which was challenging.

Lunar module: The students built a lunar module made exclusively from things they brought from home. Eventually, they added motors to make the LEM move. In both of these labs, the students felt they started small, using the simplest materials, and later, as the labs progressed, more complexity was added. This was the best teaching method. All labs should be organized by level of complexity, beginning with simple easy steps.

HOW TO IMPROVE THE MOTION FUNDAMENTALS ACTIVITY

The students noted that the motion fundamentals module as written was rather boring and did not make a lot of sense, especially because the equipment did not work. In their own, words, the students came up with the following suggestions a few days after the interview, which they wrote up on the board and which in turn were emailed by the robotics students. The teacher noted that she did not think that the graphs (suggestion 3) could be made simpler than they already are, and that clarification for suggestions 5 and 12 is needed.

In general, the students feel that they needed more background on all these activities in terms of how they tie into the real world. They wanted to know where the ideas came from, what problems prompted the idea (even a historical perspective), what was tried and why, what worked, and what did not work. The students thought that the videos included with the PAC were pointless. The transportation video was not at the high school level: it did not explain how engineers build things nor how engineering principles are used. The students wanted more information, for example, on bridge construction; one said that the videos do not include “stuff that keeps you wanting more.”

1) Make sure sensors work
2) Design a better collision sensor
3) Make graphs easier to understand
4) Have an obstacle course
5) Hardcore materials (?)
6) programs easier to adjust
7) better cars for sensors to see.
8) better track
9) Explain the math on the students sheets
10) clarify how to adjust the sensors if and when it's necessary
11) easier language in handout
12) scales easier to adjust (?)

Northern New Mexico Volunteers

The interviews with facilitators focuses on two areas: (1) whether there are civil engineering or transportation components not covered by the modules and (2) identifying the salient features of the modules that teachers find useful. In this particular case, two TRAC Volunteers from the New Mexico State Highway and Transportation Department were interviewed together.

BACKGROUND INFORMATION

Mr. Orange[*] is an alumnus of the school at which he volunteers. He graduated in 1984. He was recruited by Mr. White[†] and has been involved for the last two years. Last year, he visited the school twice a year, but since he was promoted, he hasn't been able to be very active in TRAC. The teacher he works with at that school is "very aggressive" when it comes to TRAC and is one of the best teachers there, so he feels that his reduced involvement probably hasn't hurt the program too much.

Mr. Orange feels as though the program has really brought engineering out to the students, who didn't know what was involved in engineering prior to TRAC. In his opinion, the program works because is related to real life. The students get to see how transportation engineering problems affect them as drivers. For example, they were very interested in why there were speed limits and in the newly installed cameras on traffic signals. This encouraged them to ask more questions about what else engineers do.

The role of the volunteer has been

(1) to be available when the teacher needs assistance,
(2) to give explanations of activities from a different perspective, and
(3) to expand on the module after the teacher has done the activity with the class.

The volunteers are not as integrally involved in the activities and they are more likely to forget details of the activity than is the teacher who uses it in the classroom. For that reason, Mr. Orange felt that it should not be incumbent upon the volunteer to lead the activity. The volunteer shares their real world engineering perspective with the students, like a guest speaker. However, some teachers are unstructured in their approach and are not very much "into" TRAC. These teachers sometimes see a TRAC day as a day off.

Mr. White made several comments about recruiting volunteers and teachers. They have tried to recruit schools "cold," without the school actively requesting TRAC. Sometimes the teachers are very excited about the program, but later leave, and no one will then take TRAC on their place. Turnover is definitely a part of the problem. Sometimes the principal is very excited about TRAC, but the teachers won't use it. Some teachers see the program as a new computer for their own use, not for TRAC use. Some teachers tell the volunteers not to come, and in some cases, volunteers drift away for various reasons and the teachers drifts away as well. There needs to be more evaluation of the TRAC PAC's use to make sure the PAC is being actively used.

[*] Not his real name.
[†] Not his real name.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

Many of the activities in which the volunteer participated were done as demonstrations. Since there were 20 to 25 students in each class, some activities were done in groups of four. Initially, he wasn't aware of any activities that didn't work in the classroom, although both interviewees later mentioned problems with PC-Solve and the manuals.

Sound Module: In this module, Mr. Orange introduced the concept through the use of noise barriers. He began by describing a citizen complaining about the noise from a nearby roadway. He then helped the students test how well various candidate sound barriers worked, such as vegetation, wood, brick, etc. They then picked the best noise wall. This activity was conducted in groups of four, with the teacher explaining the project to one group while Mr. Orange talked to another group about how the activity applied to the real world.

Motion Detection: The students really enjoyed the motion module because it was hand-on and they could see their results immediately. Mr. Orange let the students do the activity by themselves and then asked questions.

SimCity: Most of the students had the newer version of SimCity at home and thus, thought the old version was too slow. Students would take home work that they had done in class. This reflects a need to keep pace with the industry.

The **manuals** are too wordy. They need more pictures. Reading the manual is the last resort. The pictures hold the students' attention better. The student manual could tie into the computer video card for real motion visual aids.

PCSolve is all numbers and reading and doesn't hold student interest. The teachers don't want to take the time to figure out how to use the program, especially since it's an old DOS program and not technologically current. It's just as easy for the teacher to write the equations up on the board. The teachers are not using it to it's full potential a trainer. Graphing calculators are not supplied by all schools, but they were useful where available

IDEAS FOR FUTURE PAC MODULES

Outside of updating all the systems in TRAC, the volunteer couldn't initially think of any new modules that should be added. However, the other volunteer had several suggestions and these generated additional suggestions from the first volunteer, until they were collaborating on new ideas. There suggestions were as follows:

The yellow light problem is currently too technical. Mr. White felt that it was time to take the next step and graphically create an intersection with moving cars and a visible go zone, something like some of the traffic simulations in Netsim**.**

Mr. Orange felt that a *traffic safety module* was needed, especially in light of teenager's high fatality rate. Some traffic safety principals were used in the yellow light problem, but not those specifically applying to teenagers. He thought that a module on the physics of collisions would be very interesting to this group.

Mr. White had been disappointed in the *ITS module*, since it was a series of questions that the student could go through only once. It should be more interactive and allow for multiple solutions. He also felt that such a module should talk about some of the ITS applications, like video vehicle counters.

Mr. White also felt that something on *materials* was missing from TRAC. Students could design a formulation for concrete and then actually mix up and test it's strength. They could compete to see who could make the strongest concrete (or asphalt). A module like this would also have the advantage of having math involved, including notions about proportions.

Mr. Orange suggested that a *concrete canoe race* like the national competition be included in the TRAC. This would better prepare them for the college undergraduate races sponsored by the American Society of Civil Engineers.

He also liked the *Popsicle stick bridge competitions*, in which the person whose bridge could hold the most weight won. He suggested that this activity follow the use of the Bridge Builder program**.** More specifically, the competition would include four different designs as a starting point (cable stay, super span, etc.). There would be some explanation of how each works so that they wouldn't have to figure this out for themselves and risk failing at it. This activity would be accompanied by examples of bridges in the real world, showing how they are built. It was their feeling that there were too many words in TRAC as it was and that slides of examples, in this case bridges under construction, should be part of the program.

When asked if there were any materials easily available at NMSHTD that could be used in the classroom, they suggested using crash cushions or guardrail as part of the deceleration and motion unit to show what actually happens in a crash. Samples of posts and other breakaway devices could also included, along with videos from private companies of their tests. After the interviewers suggested an example of retroreflectivity demonstrations from a company such as 3M, the interviewees went on to say that samples of tapes and striping could be used to show the kids how reflectivity is achieved and how the angle of incidence affects the reflectivity.)

It was suggested that the TRAC regional office have a video lending library with the volunteers having access to the materials. The students really enjoy the videos of real world things, as well as things they can touch and hold.

When asked about student follow-up after graduation, Mr. Orange thought that this might be a good school to select. The guidance counselors keep track of their students and know their alumni pretty well, since the students are there from 7^{th} through 12^{th} grade. Being a small school helps in this effort -- each graduating class is generally 50 to 60 students. The school takes pride in the number of students they send to college, and the students who don't go to college tend to stay close to the school, since it is family oriented and has a strong alumni association. The teachers might be willing to relay names of TRAC students to the volunteers.

Teacher from New Mexico School 4

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs.

- The teacher (Mr. Red)* has been teaching for five years and has been using TRAC for three years and just received the update last month. He felt that the update looked good and seemed to be more user friendly. The first year he used TRAC was a "learning year, with his highest use in the second year.
- He tends to use TRAC most with his freshman physical science classes and with his physics classes. Some of the modules are too hard for the freshmen, but some he can have them do on their own.
- Mr. Red used TRAC most often in demonstrations, although this mode of presentation is not as effective as having the students actually do experiments and activities. TRAC would be more effective if several groups of 4 or 5 students could work on each activity simultaneously. The school is getting a computer based projector which should help the demonstrations, but nothing can take the place of doing the activities.
- St. Michael's has a new science lab with 12 networked computers. He would like to load some of the TRAC software there (such as Bridge Builder), so more students could use it.
- Mr. Red attended the annual TRAC meeting in Denver in August with several colleagues. He also attended training done by Tate Jackson, which was very good. However, he felt it was still up to him to learn how to use TRAC by himself first.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

Bridge Builder: The teacher likes this activity and will be using it in his physics classes soon.

Motion Module: The teacher has used this module in the past and plans to use it in January to study momentum in relation to vehicle collisions. Using different materials, the student construct crash barriers to reduce collision forces. (He would like to put emptied eggs in the front of the cars as subjects.) The students like this approach and are interested in the idea that the human body absorbs energy not only during the traffic crashes but also during physical activities like jumping. This ties the activity into real life for them.

SimCity: The teacher uses SimCity as class motivation. When students finish an algebra assignment early, they get to use SimCity. Sometimes they can work in small groups on this.

Sound Module: The oscilloscope created by the program worked very well with the students. The teacher set the activity up in the back of the room and just let the students stumble across it during the first 10 minutes of class. This allowed the students to discover on their won that sounds they made different patterns on the oscilloscope. The tonettes provided in the PAC to generate sound do not work well. He had to had the students bring in their own instruments from home. The sensor did not need recalibrating when it first came, but did later (he used the software calibration). When questioned, he didn't feel that the sensor was too sensitive and he was able to conduct the activity as written. He feels that the module would benefit from the addition of equations for frequencies and more math.

* Not his real name.

Force Module: The teacher is the fencing coach at St. Michael's and has adapted the equipment so that they can use a fencing foil as the force generator. This has helped the students use the results to decide what clothing is most protective when fencing. The students seem to like this activity. Mr. Red had no trouble using the software to calibrate the force probe

MAGLEV: Some students take his class just to get to do the MAGLEV activity. The students liked making the MAGLEV cars, and several went out of their way to be creative and make cars that were uniquely their own. (Mr. Red still has several on display in his room!) They really like the competition. There are two categories – most original design and fastest car. When asked about students who might not like competition, Mr. Red mentioned that he lets some students run their cars before or after class, and simply turn their designs into him. His physics students all seem to be very competitive. They will stay as long as it to build and run cars. They prefer to race the cars side by side in heats and to root for one car or the other.

Although Mr. Red begins this lesson by having the students do a report on MAGLEV projects in the real world, the activity is nothing like real MAGLEV trains. This is something of a problem, since the students use the Internet to research the project.

Yellow Light Problem: Mr. Red hasn't used this in class yet but he may try it out to see how the students like it. He may amend the problem based on their reaction. The students are not shy about telling what they like and dislike about activities.

PCSolve: Mr. Red hasn't used PCSolve or any other PAC modules besides those shown above.

Improvements for the Student's Manual: The students seem to have trouble going through the Student manual by themselves. It night be good to tie some of the actual computer screens into the Student manual, or putting help online. The teacher felt that the new windows version of the TRACPAC might be more intuitive and thus, better.
Improvements for the Instructor's Manual: Mr. Red feels that the Instructors' Manual is a "little dry," but that it works for him.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

What works?

Mr. Red mentioned some labs that he does in his classes that students love. For instance, students love the "pickle lamp." He splits the wires in an ordinary lamp cord and wires each to a nail. He then places the nails in a large pickle, with the ends being within about 3 inches of each other. He plugs the cord in, running current through the pickle, and it eventually begins to glow because of the electrolytes.

One thing that works is tailoring the level of difficulty to the individual class. Mr. Red's advanced placement physics class can't do the sound module with the tonettes and be satisfied. His general science classes may have trouble with frequencies and wavelength and if they are not ready, they become frustrated. Some TRAC modules try to do to much and others either don't try to do enough or try to do it at the wrong level of difficulty. Of course, he mentioned that "you couldn't make one PAC that would fit everybody," but that the current PAC represented a good start.

Hands on activities involving things students can touch and hold work well, as do activities that allow students to see things change. For instance, to demonstrate momentum, having two rubber band cars crash into each other and observing where the vehicles end up works very well. The students also like to measure things, especially when they are pieces of a larger something that has been broken. However, they need a reason to measure. They are happy to weight a piece of string until it breaks and then measure the resulting pieces. Having students work in groups of four or less also works well, especially groups of two. The biggest problem that Mr. Red sees with TRAC is the fact that the PAC comes with one set of equipment (and software) and does not allow several groups to perform experiments simultaneously.

Labs that use the students' curiosity, that involve things they have seen or read about, allow them to put their personal experience (and opinion) into the lab. For example, the fact that a car had recently broken the sound barrier was a good stepping off place for further discussion of the concepts involved.

According to Mr. Red, a few of the students thrive on "high tech." It's just what they do. His younger students like interactivity – it grabs their attention. His feeling was that you need both to teach well, but if he had to choose, he's choose interactivity because it reaches more students.

Having the volunteer also works with both the teacher and the students. The volunteer can answer the teacher's questions the first time they try a TRAC activity, and they can also tie the activity into their own experience of working in the field for the students. Any guest speaker is a plus with students and Mr. Red often treats the volunteer as a guest speaker (even though it is often hard to arrange for the volunteer to come to the school because of their busy schedules). Their state volunteers have been really proud and excited about what they do and have been really good in the classroom. Finally, a volunteer can help deal with problems: it is good to have the students see stuff fail (but the teacher noted it is helpful if he has gone over the labs first; that way, he can be prepared for pitfalls).

What doesn't work?

The teacher gave several characteristics of labs that do not work:

- *Simply doing an activity without a purpose doesn't work.* Labs need to be based on scientific questions to hold students' interest.

- *Students also need to be left alone* long enough to feel as though they are discovering the lab independently, but...

- The *teacher has to stay close* enough to know when they are getting lost.

- *Equipment must work*. When students don't have enough materials or when equipment doesn't work (or won't work consistently, as is the case with some of his hand-me-down equipment), students lose interest. If they are looking forward to seeing something happen, they may become disappointed. In this vein, some of the TRAC equipment needs to be fine tuned. The tonettes in the sound module don't work very well. Also, something needs to be done with the MAGLEV track to keep the cars from catching in the joints. (Sometimes this is a good feature, since it forced the kids to figure out how to get around the problem.)

The teacher also felt that some less experienced teachers may have trouble tailoring the TRAC equipment to group size. He reiterated that this is the biggest problem with TRAC – that there is only one set of equipment. This results in teachers having to merge labs for small groups or for the class as a whole. Having the volunteer helps to offset this problem somewhat. The volunteer can help the "strugglers." Also, the teacher can do the lab in two days or cut the class in half, with the volunteer taking half the class. Even in this instance, the group sizes (10-15) are too large. The optimal group size is four or less.

On this same topic, the teacher suggested that for newer teachers, it might be appropriate to include some logistical ideas in the teacher's manual on how to actually use the PAC in a real live classroom. This would cover, for example, how to direct students to the PAC: *what should the teacher do differently depending on*:
--if the PAC activity will be done with small groups or as a demonstration for the entire class?
--if the activity is part of the curriculum or an extra assignment to be done during lunch or after school?
--if the activity meshes well with a group size of two, four, or five students?
--if the PAC will be juxtaposed with another activity (e.g. on one day, half the class does the PAC

and half does a different lab, and then the next day they switch)?

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

The teacher felt that because he taught at a private school, he had more freedom in how he met the learning objectives of his classes than did public school teachers. Since private schools don't have to administer the statewide standardized tests on the SOLs, he doesn't have to teach to the test, which he would hate to do.

In order to determine if a TRAC module meets the requirements of a learning objective or SOL, one has to set aside a couple of hours to do everything in a module on one's own. This allows the teacher to determine if the module will work with his or her students and which SOLs it satisfies, if any. He tends to change some aspects of the modules "on the fly," to make them work with his students. He hasn't written his changes down but intends to do so and forward then to the national TRAC office. The training is not aimed at using TRAC to meet the SOLs, but rather is a "how to" for the equipment.

IDEAS FOR FUTURE PAC MODULES

Something on optics should be added. For instance, consider the infrared installation in some of the more expensive vehicles for use in bad weather: it could be great for kids to use to "see" in the dark.

A traffic congestion module could help the students figure out why this is occurring and how traffic engineers use methods to alleviate congestion. This could be in the form of a debate in social studies class. Mr. Red feels that his students are very resourceful and could even do an independent project on this topic.

There should be a hazardous materials module, focusing on the transportation of hazmats. This could be in the format of a simulation. This is especially relevant to his students, since a bypass built has just been built in their area specifically to route hazmats outside the city.

Regarding the hazmat concept, the teacher noted that it might be a mistake to tell students exactly the format they should use: instead, he explained that one might even ask students to "build an activity" and then let the students on their own decide the format – they might choose cardboard, Legos, or something else entirely.

Finally, Mr. Red has several students who took physics as juniors and are now seniors. He will get in touch with the interviewers concerning how they can best contact the students.

Students from New Mexico School 4

Students in Mr. Red's physical science course needed to accomplish a lab during this class. Mr. Red was able, however, to permit the interviewers have approximately 25 minutes with the students, during which they were queried as to what they thought it meant to be "a transportation professional." During this time students gave a number of answers – race car driver, truck driver, automobile engine builder, etc, and the interviewers encouraged consideration of divers aspects of transportation, such as a lobbyist for the trucking industry. The students were then asked what kinds of skills one would need to learn in school in order to pursue these careers.

After this 25 minute discussion, the students began their regularly scheduled laboratory work in groups of four. During this lab work, the two interviewers split up, talking to the individual groups, asking them in detail what they liked, did not like, and what they would do differently with respect to their previous science activities.

Group 1

Activities that are liked (or suggestions for improving the way in which they are done) include:

- building machines and presenting [what has been created]
- picking your own lab partners and working together
- this lab that is currently being done, where you get to mix a substance and even play with it in your hands! In this lab, we actually get to do something – the lab is hands on.
- [if you have to give a test], make it a ten-question test where the questions are very difficult but you give a hint. Better than a written test, though, would be the [requirement to] build something.

One student mentioned that you don't want a lab where you have to taste anything.

Finally, one student mentioned some possible PAC activities as being:

- in driver's education [training for student drivers] teach students the meaning of the changes in sound that result when the driver [or the car automatically] shifts gears.
- it would be fun to teach a person to fly in a plane.
- teach how to get help [with navigation in order to avoid getting lost]

Group 2

The second group noted gave some suggestions that make labs better, all of which have to do with making the lab more hands on. One group member mentioned that dissections are fun, and another pointed out that charts are better than long written responses because the student is then give more time to do the actual lab. By contrast, one lab that was not well liked had involved two blocks, where only one person actually did the lab but all four persons had to provide their own separate write up for the lab.

Yet while this group did have some comments on the labs, it is the interviewer's opinion that they had far more interest when one student mentioned that she liked her debate course, because unlike science, she could put more of her own thoughts and opinions into her work: there is not just one right answer that you have to uncover. That student and the other group members listed several topics they found to be of interest: abortion, the legal driving age, assisted suicide, and capital punishment. It is not just the topic that makes debating of interest though: characteristics such as interacting with other people, the oral presentation, and the impromptu components are important.

This group also wished that the school day (or the class period) could be shorter, because it is tough to stay on the same subject for longer than about 30 minutes.

Group 3

In the limited amount of time remaining, the group noted that listening to lectures is not fun and also recalled a rather boring lab that involved making a map of the ocean floor. The students had ideas for how to make the lab better (such as using larger grids) but mentioned that what ruined the lab was the fact that there was only one way to do it, and that way did not work.

Principal from New Mexico School 4

The purpose of the interviews with principals is to identify generally the factors that affect whether or not an educational aid, such as the TRAC PAC, will be used by the school. Hence the principal is able to offer insight from an administrative angle.

FACTORS DETERMINING WHETHER AN EDUCATIONAL ACTIVITY IS USED

According to brother Richard, a number of factors are involved in deciding whether to purchase a new program for the school. These include:

- *Cost*: Cost is one of the first factors considered in implementing any new programs at St. Michael's. "Freebies" are good, but expensive programs ($3,000 plus) involve more critical decision making. They get quite a few offers from traveling troupes and have to be skeptical, since some want as much as $1,000 for their performances.

- The "*Foot in the door*": Like some other principals interviewed, brother Richard pays the least attention and is most skeptical about sales promotions received by bulk mail. He may route the mailing to the appropriate teacher or department head if it looks especially promising. Salesmen are also not always a credible source. The programs that have the best chance of being purchased are those brought to him by teachers or parents. The parents of one of his students, the TRAC regional director, brought him the PAC. The director met with the teacher (Mr. Red) who pilot tested the course and liked it, as did the students. Brother Richard has watched the MAGLEV competition and mentioned how involved the students were in the project; he could conjecture that students could learn about concepts such as velocity and acceleration.

- *Career programs*: Brother Richard feels that the career programs benefit the students more than curricula that don't involve the "real world touch." Los Alamos National Laboratories sends physicists and engineers to make presentations and to ask teachers which lessons they would like help with, as part of their community outreach program. Some parents are involved in science in one way or another, and other labs, like Sandia, have sent speakers. The New Mexico Museum has an outreach program covering the topics of history and culture, and St. John's College sends out a Shakespearean troupe to schools.

- *Purpose*: Brother Richard mentioned that they are also skeptical of programs that do not seem to have concrete purposes but appear to be devised to make money.

INSTITUTIONAL CONSIDERATIONS

According to Brother Richard, if a program is self contained, there are not institutional obstacles. On the other hand, just because there are no institutional obstacles doesn't mean that a program will be implemented. The real decision is made by the teachers and department heads, since new programs affect the whole department. Programs that are acceptable to the school administration must come with training.

Cross curricular programs, although rare, are sometimes adopted at the school (Spanish art/Spanish history; math/science; junior high English/junior high science to promote reading of science books). It was noted that reading, writing, and critical thinking skills are often what holds a student up in a physical science course! The principal mentioned a desire to do more cross curricular work; an example was given where transportation aspects could be tied into a government course with the students studying city management and city planning.

However, sometimes a teacher in one discipline will not want to give up valuable time to collaborate with a teacher in a completely different department. In that case, for example, a teacher may say "there is so much material that I want to cover, that I simply cannot afford to lose a week."

Brother Richard mentioned that he had an initial reservation about the TRAC Program, since it provided only one computer for 20 or more students. He felt that any more than five students around one computer was too many. However, the school hopes that computer projection [where students sitting in their seats can all look up at the screen and see the computer display, just as they would watch a movie] will help with this problem.

New Mexico State Highway and Transportation Dept. Research Bureau Chief
(Representing the) Alliance for Transportation Research

At the recommendation of the New Mexico TRAC Director, the interviewers met with a representative of the New Mexico State Highway and Transportation Department (NMSHTD). Although chief of that Department's research bureau; he was interviewed as a representative of the Alliance for Transportation Research, which plays a key role in New Mexico's TRAC program.

BACKGROUND INFORMATION

The Alliance for Transportation Research funds the TRAC program in New Mexico. The Department Research Bureau Chief works closely with this alliance, whose overall mission is to advance transportation research efforts by using transportation, environmental and defense funding to leverage additional projects.

OTHER EDUCATIONAL PROGRAMS

Note that the ATR sponsors three other educational projects besides TRAC:

One such project involves *awards for students entering science fairs.* The ATR is offering the first ever award in science and ethics for students. Competent work in any application of science where a high school or middle school student gives consideration to the ethical implications of the work is eligible. Winners receive savings bonds and trophies, as well as a "library passport" to the ATR Institute's web page and to it's library at the University of New Mexico. This passport is one way to keep in touch with promising students in the sciences. How often and for how long students use the passport could be an *indication of the effectiveness of the awards program and of the TRAC program*, once all TRAC students are eligible for awards. As long as students use the passport, they are probably still involved in scientific investigation and can be contacted if needed. According to the interviewee, many people involved in the ATR sponsored programs like TRAC have anecdotal evidence that the programs are effective. While everyone has success stories, ATR will need quantitative evidence of the program's impact in the future.

A second project is also award-based*: the ATR gives awards for the projects entered in a Native American science fair that best follow the traditions of the Native American community and that most preserve their cultural values.* Local elders judge this competition. One winning project involved a 5^{th} grade student from the Los Alamos Indian Reservation who learned how to identify animal tracks from his grandfather. He then developed a typology of prints and a method for using the print data to determine the health of the herds. From these data, more could be done to protect these animals. The Native American family took great pride in the help they gave the student, as opposed to non-Native Americans, who sometimes hide their involvement in their children's science projects. Note that the project accomplished two broad goals that may appear subtle but that are actually quite significant:

- the student showed that what one does with the family (e.g. the grandfather) may be shared with others, especially in a scholastic setting. This encourages the sharing of knowledge among generations.

- this project places an application of science (e.g. deducing a typology of prints) at an academic level.

Although not explicitly stated by the interviewee, it was implied during the interview that this project contains an important ecological component as well.

A third program is where the *ATR holds an annual awards banquet for students, families, and teachers.* Travel and attendance for these individuals is funded by the ATR. This is a great opportunity for the students to share ideas, integrating the efforts of the many students who participate in various educational programs and events, and it represents an occasion of pride for the families and teachers. Some awards for professional researchers may be given out at that time as well, promoting research careers. The ATR plans to expand their system of awards so that they will be available to all TRAC students.

THE ATR AND TRAC

The interviewee's decision regarding which projects to fund depend as much on the character of the people involved as the content of the project. Making personal contacts within an institution gives one a better idea of the quality of the work than does the reputation of the institution. This philosophy has never served him wrong. In terms of TRAC, the interviewee knew the Regional Trac Director from the Human Resources Division of the New Mexico State Highways and Transportation Department. The Director was behind the TRAC program 100%, and the interviewee knew him to be an ethical person who had good judgement and who could be trusted to deliver on his promises. Their relationship was the basis for the research bureau's and ATR's involvement in TRAC.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

The interviewee began by discussing how different students have different learning styles, and that alternate teaching strategies were required to meet these needs. The best teachers vary the strategies they use to get through to students. Veteran instructors often use TRAC to offer a set of teaching strategies. In the future, these could be matched to various students' learning styles through educational assessment. TRAC may act as a catalyst to encourage more teachers to address the alternative learning styles of their students. Much of this could be done during the TRAC instructional workshops for teachers.

In order to assist teachers in using TRAC, the interviewee felt that it made sense to map TRAC activities with the national or state standards of learning (SOLs). However, he questioned who should do this mapping. He felt that rather than having TRAC personnel do the mapping, perhaps TRAC should provide teachers with a method for determining which SOL a particular TRAC activity satisfied. He felt that this was the responsibility of the states, rather than some national group. He recommended convening a state panel to make these determinations.

THE FUTURE OF THE TRAC PROGRAM

[*At this point, the interviewee explicitly pointed out that what he was about to say reflected his own point of view rather than some sort of institutional consensus*.] According to him, TRAC's current premise is to recruit underserved students into careers associated with transportation and engineering. However, there are other underserved populations of students that the program is not targeting. The interviewee favored expanding the definition of underserved to include blind and deaf students. It was his opinion that TRAC is really just getting off the ground, and what is being done right now is the best that can be done, but for the future, TRAC could develop enabling technology for the deaf and blind so that they could pursue not only TRAC activities, but also careers in transportation. An illustration of a way to do this while respecting the culture is to get permission of the elders to make audiotapes in the classroom [to help blind students]. On a related note, the ATR has hired a consultant to study information technology for underserved students; one outcome of this work may be ways to make TRAC more accessible through information technology. If we are to be successful, though, the interviewee points out that "we need to push this definition."

Another group of underserved students are the children of persons new to the United States or Native American students. Many of these children do not speak English as a first language. Respecting the culture of these students in terms of oral traditional is important. Perhaps making TRAC tapes in Navajo might be a first step in this direction, with Navajo-based TRAC activities a later step. Most state agencies do poorly in promoting reading among non-English speaking children. Maybe reading should be taught in the native language first or concurrently with English.

One way to extend the influence of TRAC is to expand the number of volunteers. There are ATR mentors and a few consultants who are active in TRAC, along with the highway district engineers and their staff members. We need to identify new mentors, including respected persons in the local communities.

In summary, Research [Bureau] has at least three goals that relate to TRAC:

- *To evaluate how to take this national program and make it accessible to the broadest underserved community.* Once this evaluation is complete, the process can be shared so that every other state may use it in relation to their TRAC program. Right now, TRAC is reaching some underserved communities, but there is more that can be done. Another way of phrasing this question is to ask what are the enabling technologies that should be considered.

- *To assess quantitatively the impact of programs such as TRAC.* As suggested at the beginning of this narrative, the "passport" program has tremendous potential to track what students do once they are exposed to TRAC. Two measures of TRAC use – how many students are seeking mentoring services (from ATR or NMSHTD resource staff) and how many students are accessing the PAC materials – may be monitored through this passport program.

- *To make the PAC educational in its own right*. Keep in mind that the person attracted to the PAC is an educator to whom it appeals, but the interviewee pointed out that there is value in having a PAC that educates not only students but teachers as well.

WEST VIRGINIA SCHOOLS

Teacher from West Virginia School 1

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs.

- The teacher typically has classes with between 15 and 25 students, and he teaches chemistry and physics. He is also chair of the science department.
- The teacher has been involved with TRAC for about two years. He originally became involved in TRAC because of its career emphasis. For the first year, he received training on a Saturday; he had to give up his own time to attend. For the second year, he received training over a two day period at the regional level within his state.
- The training was helpful, but three problems arise for a teacher once he has seen all of these modules in action: first, what modules should be done in the classroom, second, where within the lesson plan or curriculum should these modules be implemented, and third, how well can the TRAC PAC mesh with state learning goals and objectives?
- Beyond training, no one from the state DOT has contacted the teacher about using the PAC.
- He was able to name, however, two persons who had previous PAC experience. One engineer only three years out of college had attempted to work with the students in the past but had been so nervous in front of the students the first year that the activities were not very useful. The second year the volunteer was more calm and used audio-visual aids but still could not get the students interested; neither the volunteer nor the teacher knew why this was the case.
- Being in a university town is not a panacea. The nearby university does offer some advanced classes beyond what the high school offers which students may attend, but there is also some competition between the college and the high school. Sometimes it’s just hard to get students to concentrate on their classes, even though the material is important and as advanced as what they might try to take at the college. (For example, some students abuse the system by getting out of high school to take trivial classes, such as weightlifting). The fact that the school is overcrowded does not ease the situation.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules’ strengths and weaknesses, including the utility of the instructor’s manual and the student’s guide.

The teacher has not used any PAC modules per se, but he has made use of some of the equipment and has also read the manuals to garner ideas for student research papers. One reason he has not used many modules is that it takes a considerable amount of the teacher’s free time to set up equipment and get it working. There is some duplication of effort between PAC materials and other materials (e.g. microphones and force probes), and once a teacher has something that works, it can be difficult to change to another medium. Unique to the PAC are Maglev, the software packages, and the lesson plans which the teacher can read quickly to see the expected outcomes of the labs. The lesson plans are not complete but they are concise, saving some teacher time.

The *manuals* are useful in that they are short and concise, but they could be improved by giving sample outcomes and sample data. Some teachers hate to say "I don't know" when something does not work, and this way the manuals could help indicate whether an experiment is on the right track or not.

PAC *Motion detectors* are not used, but there are other activities released before TRAC that do contain several Vernier motion detectors that are used, in groups of 4 or 5 students and with graphing calculators.

Note that the *sound probe* usually needs a lot of room, with a range of 3 to 15 feet; any sound generated within that range will be picked up, along with the intended stimulus. Again, as is the case with light, temperature, and motion, PAC materials are not needed since CBLs have this covered.

Bridge Builder needs updating.

SimCity was set up by a student, but it doesn't make sense to the teacher. He notes, however, that the students will figure this out!

PC solve needs to be made more user friendly. The teacher could not get this software to work. It is also a concern that students don't know how to draw a graph by hand; this is something employers will probably have to teach them, unless the schools begin teaching this as a precursor to using the software.

TRAC PCs should have Windows rather than DOS. Some schools really need these computers.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

The teacher gave several examples of activities that are successful and unsuccessful, his thoughts on technology as applied in the classroom, and other programs that link school curricula to outside activities.

What Does Work?

- *Transportation Research Papers*. Students follow a formal procedure for doing a research paper on transportation topics that have been synthesized from chapters six through eight of the PAC manual. Specific steps are included, such as creation of bibliography cards, doing a rough draft and final paper, and making a presentation to the class using either PowerPoint or a poster. Examples include tracing the history of transportation, interpreting how the development of the Interstate highway system has influenced where we live and work, and how the growth of transportation related industries (e.g. tire and petroleum) have affected the U.S. economy. Additional topic questions are shown in a handout from the teacher.

- *The "universal indicator" lab*, where students dissolve samples of a solid substance in solvents and determine, based on their results, what the unknown substance was. This may include the "colored bulb effect."

- *The old PSSC labs and similar activities*, that are open-ended. Questions that ask "What did you find" and "What would you predict" are excellent ways to get students thinking, even though they find it disconcerting. The only problem with the PSSC labs is the reading level is about 14^{th} grade, but the ideas are sound; in fact, they are the best labs this teacher has seen.

- *Team projects*, which are interesting because the personalities of individual students are shown; some are leaders, and some want to be carried. Also team work is a necessary business skill, as is leadership. The teacher also indicated philosophical problems with setting up a "group test"; the group projects are a much more fair way of assessing student achievement.

- *Experiments that are showy, colorful, and noisy*. If students have any kind of interest in science, then these type of activities will work. Things that blow up or crash are a lot of fun.

What Doesn't Work?

- *Cookbook labs*. Anything that bottle-feeds the students is boring.

- *Labs that have not been tried by the authors*. A few years ago, "microscale" experiments were touted by some books, but they simply never worked.

- Suggestions that require the teacher to learn PowerPoint (or some *other time-consuming package*).
- *Technology for technology's sake*. Most of these students are already more advanced and own more sophisticated gadgetry than the school offers. This does not "grab" them.

- *Changed procedures for updating labs*. Publishers used to update lab books for free. Now there is a charge for updates. (As an aside, the teacher mentioned that the TRAC program should be "up front": in terms of funding and support.)

What about Technology?

It is tough to keep track of [communications] technology. For example, at the time of the interview, the school technology coordinator and the county technology coordinator had not agreed on a set of standards: the county person fixed the hubs at 100 MHz rather than providing more expensive switching hubs, meaning that the cards within many of the PCs would have needed replacement. Soon thereafter, though, the wiring was examined by another company and improvements made. The County Technology Coordinator decided to install switchable hubs which should allow computers with cards of any speed to be able to access the Internet; this upgrade should completed soon. Also, there are five Internet connections per classroom, but only one has been activated per classroom. Finally, the Casio graphing calculators are more complex than those from Texas Instruments; the teacher does not want to make the students simply learn yet another technology that accomplishes the same things that can be done with existing equipment.

The optimal group size is two to four persons, but sizes of three to five people are necessitated by the constraints of the classroom. If there are too many people in a group, then only one or two will be working.

One caveat regarding technology is in order: the more technologically sophisticated the activity, the more preparation time is required by the teacher and the less work is done by the students. For example, in the past, students did an activity that entailed them measuring and recording the temperature of a substance every 15 seconds; students then used these data to create a graph. The "newer method" is for the teacher to spend time working with probes that automatically take these measurements and feed them to a graphing calculator, which in turn automatically creates the plot of temperature versus time. The students simply watch what happens in this instance. Furthermore, after taking an hour of the teacher's time to set up seven stations, after a couple of periods the class and teacher determined that the equipment did not work!

What other programs are there?

There are other activities that possibly this high school could be involved with, although there are problems with each. For example, it is tough to arrange bus transportation for these extracurricular activities.

- *JETS* (Junior Engineering Technical Society) is a possibility, but that costs $100 or more to enter.

- *Science Bowl* (sponsored by the Department of Energy). The first year the event was organized the high school did not participate due to late notification. This lead to political pressures. (This occurred seven or eight years ago.) Since then this high school has won the competition four or five times and has represented the state at the national level in Washington DC.

- *RuralNet* – a program where schools are tied together in their efforts to sample water and monitor water quality.
- A program with NASA that involves *tracking weather* with the Internet.
- Mechanical Universe Telecourse and Project Prisms are other examples of good activities: TRAC does not need to reinvent the wheel in this department!

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

Some PAC modules tie in nicely with some concepts such as motion, but the rest can only be used as enrichment topics. For the past six or seven years, textbooks have been focusing on new goals and objectives which are specified within the appropriate textbook activity. SOLs should be key, but right now the teachers in this school still run their own classrooms. The SOLs are becoming burdensome, though, because one spends so much time documenting how each activity relates to an SOL; the teachers are required to document which SOLs they have covered each day.

Also, note that the "Senate Bill 300" (which several people have mentioned) refers to the state legislature's efforts to get students to declare a track of interest by 8th grade after doing career exploration in previous grades. One of the problems with this bill is that while supported by private industry, it is not receiving the corresponding logistical support that is necessary for its success (e.g. businesses are not providing students with shadow days, where students observer a professional for a day).

IDEAS FOR FUTURE PAC MODULES

The teacher suggested several ideas for both PAC modules as well as activities that he himself is likely to pursue, whether or not they become part of the future PAC.

- *Give more ideas for the research papers!* The PAC manuals suggest topics, but these have all been done, and they need more transportation areas that students can investigate, such as Maglev, traffic flow, and alternative transportation modes.
- Look at the *Texas Instruments CBL* (Calculator Based Labs) for more ideas on activities that work.
- Rather than activity-specific technology, the lesson is that it may be appropriate to teach students how to use *technologies that will serve them outside the classroom*, such as Word and Excel. In practice, this could be coordinated with the school computer labs – even the English Department computer lab.
- A *speakers' bureau* would be helpful. Experiences of others have been helpful; one former student came back to the class and told them that one can get a solid undergraduate degree at a state university, thereby saving money, and then wait until graduate school (e.g. law school) to attend a more expensive school. Another young but experienced representative from Motorola had come to talk to the class and had done a demonstration on making computer chips that worked well with the class.
- *Keep material updated*. Remember that schools do not generally have a budget for non-textbook materials.
- Include *sample data or sample outcomes* (or perhaps some real world data) with the activities.
- Study why the idea of a Maglev train from Clarksburg to Pittsburgh was dropped.
- There was a fatal truck wreck at the base of Cheat Mountain, yet it has taken three years to do the design, even though there was an immediate need to reduce speeds which were too fast for the road curvature.
- Tell us why it takes several days to reset traffic lights that are hit by a power outage!

Students from West Virginia School 1

Three sets of student interviews were conducted: one during a physics class, one during a chemistry class, and then one with four former PAC students during a free period. The results, by class, are shown below.

PHYSICS CLASS

The interviewee began the discussion by asking the class if they had heard of the TRAC program and then explaining its purpose. The class then discussed what people employed by the West Virginia Department of Highways did, with the class suggesting everything from clearing away road-kill to lobbying Sen. Byrd for more funding. The class also brought up some roadway projects, such as: (1) the interstate that will go from Detroit to South Carolina (through West Virginia) and (2) a road called West Run, which was being upgraded to an expressway, and which would go through some people's neighborhoods and would involve the taking some people's land. The students were interested in the fact the a WVDOH employees (along with others) would have a say in some of these decisions. They concluded that there are no "right" answers in these debates.

Students were then asked, in groups of three to five, to develop an activity or experiment that would be fun and would get high school, intermediate school, or elementary school students interested in transportation, science, or math. They were asked to stipulate: (1) who the audience is, (2) what is done during the experiment, (3) what the students learn from the activity or experiment, and (4) how the activity is broken down into easy steps for younger students, if it designed for them. Write-ups have been presented exactly as they were written.

Note also that one student raised two questions. First, it is not clear that transportation merits being a part of the high school curriculum. Second, if one wishes to influence student career choices, then students need to be hit earlier – e.g. in the 8th grade.

GROUP 1: **<u>Transport Tycoon</u> (an already existing video game)**

This game would teach students how to design roads with the least amount of money and the best efficiency.

Find the best way to travel between cities. Because someday you will need to know what roads to travel to speed up travel time.

(These students said, but did not write, that this could help solve the road rage problem as well as Knowing how to drive and knowing where you travel.)

GROUP 2: Lemmings

1. All ages
2. Package simcity and lemonings together and distribute to classrooms as examples of what civil engineering can do.
3. What a civil engineer does ok the ____ it can be.
4. Non applicable.

GROUP 3: Carbon Based Super Conductors

Carbon based room temperature super conductors
High school
Computer simulations of carbon based super conductor design.
Applications of and design of super conductors.

Group 4: (for Intermediate school)

Discussions

Uses of bridges
How and why their made
Movie on construction of bridges
View varied structures of bridges (Golden Gate, etc.)
Give and ask for examples of material for models (spaghetti sticks, tape, glue, Popsicle sticks, Lego, etc.)
Draw up a design for model
Experiment with material and begin building (use imagination)
Whichever bridge supports most weight wins.

Learn how to construct bridges
Learn more about bridges and their construction
How to brainstorm with a group.

GROUP 5

Objective: Build bridges all out of given # of tongue depressors and duct tape. Use geometric shapes and structures in design.

Goal: To make your bridge withhold the most amount of weight and fit the specific size requirements.

You learn: About design and strengths and structures of geometric shapes.

GROUP 6

1st Idea

Give a certain distance a bridge must cross
Build a bridge to scale that could support a tractor trailer, etc.
Use different arches for support as well as # of pillars.
Applied: overpasses on major highways
Cost list with fake money; figure out materials used
Learn: what shapes support best + cost of building materials

2nd Idea

Tour a public transport station such as PRT, Subway, Monorail, Train

3rd Idea

Map of a town with certain geographical barriers as well as buildings and buses.
Connect pt. A to B, shortest distance, most feasible, nook environmental and socially wind.

(Note that students attached a drawing that included points A and B)

CHEMISTRY CLASS

In groups of three students in a chemistry class who had never used a PAC developed their "ideal" transportation learning activity by writing on flip charts and then presenting the results to the class. The lead-up to this activity was to initially ask the students to describe different factors that affect transportation, and these were put on the right column of the board. The interviewers put some of the PAC activities on the left side of the board.

TRAC PAC	TRANSPORTATION FACTORS
SimCity	Bridge congestion/right turn lanes

Motion detectors
Sound module

West Run [a freeway] expansion
DUI
Stop sign in a highway construction zone
Work zones
Wrecks
Pollution, CFCs, exhaust systems
Supercars
Congestion

The students were asked "do you see a direct connection?" When students indicated they did not (or saw only a partial connection), then the interviewers asked the students to develop their own activity that would fill the gap. The students were asked to answer the same four questions as the first class.

The oral presentations had a lot of enthusiasm behind them; while the students joked around a lot, they were quite outgoing and seemed to enjoy answering questions, even with a good bit of humor. Additionally the students drew figures, even though we didn't ask for this. In one vein, this display of creativity makes sense when considering responses from both teachers and students that suggest a desire for open-ended questions. Students were queried as to troubleshooting tips and the goals of the lesson. Based on their responses, it is safe to say that the students' opinions were not hindered! The practicality of these ideas is another matter.

GROUP 1

For DUI, use private racing course and have professional drunks to drive around. Note the effects after different levels of alcohol and other controlled substances.

A simulation drunk driving game in which right is left, straight is backward, etc. The game must be realistic and could be used in drivers' education (9-12 grade high school level)

Materials

- Sit down simulator/that tilts
- Vibrating seat
- Blurred spots

People would learn to drink and driver better

GROUP 2

Super cars: hook up to a machine that measures pollution exhaust system of a regular car to show the amount of air pollution. Then hook up to same machine a super car and see the difference in air pollution.

A machine that measures air pollution.
Measure pollution 3 times a day in the same spot.

1. Morning - before students arrive
2. During a lunch
3. Afternoon while students are leaving.

See the differences.

GROUP 3: Air Pollution (this drawing is currently being digitized)

Audience: Emotionally Unstable & Impressionable 4th Graders
Materials: Two Plastic Cages
Two Hamsters
One Car
Several councilors

Lesson to be learned: Many harmful things come out of cars such as CO, O_3, CFCs, and Pb.

Troubleshooting: If Willie doesn't die – ask the kids which cage they would prefer to be in, then demonstrate with the annoying kid no one likes.

Encourage 4th graders to have their parents drive less/and/or convert to natural gas car or cleaner fuel.

(The drawing shows Wally the hamster breathing clean air and doing fine and Willie the hamster not moving after breathing exhaust).

FORMER PHYSICS STUDENTS

Four students who had participated in the teacher's AP physics class the previous year were interviewed, and their comments are shown below. While the students had not done PAC activities per se, they had done the transportation research paper and they also had insights into what makes a lab successful or a dismal failure.

All four students indicated a strong interest in science and one of the four had installed PAC software for the teacher (e.g. Bridge Builder and SimCity). That student, whose main interest was atomic physics, noted several aspects of the PAC modules (before the other three students arrived):

- The most beneficial aspect of the PAC software is that it helps one visualize the underlying phenomenon. For example, in the case of the Bridge Builder, one can see how forces and impulses affect a bridge. This student found Bridge Builder to be the most interesting of the TRAC activities.

- Along the same lines of visualization, one should consider adding some modules to the PAC:

  --vector manipulation, which is used a lot in physics and chemistry
  --a building/structural analysis program, which could even be linked to 3D/4D capabilities as well as the current bridge software
  --atomic physics visualization, again which could be enhanced with 3D capabilities.

- The software in the PAC is old; no one uses DOS anymore so we should stick with Windows based programs. (The teacher notes that the new versions of the programs were Windows based but for some reason, his computer still boots to the DOS menu. He can access the Windows versions by by-passing the first screen with a password, which he believes means he must have made an error of some sort.)

- *The TI-85 (Texas Instruments) calculator has some useful labs; since the student uses* this calculator at home, this has some good examples that PAC designers should consider. Again, this can be used to teach data analysis methods, such as basic statistics, regression, bar graphs, and other types of analysis appropriate for engineers and physicists.

- PC-Solve has been used during study hall. (The teacher later clarified that this meant that PC-Solve was used in Basic Skills Classes held during Study Hall for students needing remediation in math as indicated by scores on the SAT9, a state mandated test). The student could also see relationships between AP Physics and AP Calculus, both of which he took in the 11th grade. Yet he notes that not everyone really got around to using PC-Solve, although it could be helpful for 2D velocity and momentum problems.

- Regarding the research topics, this particular student worked with two others on the topic of tracing transportation history. The group used Microsoft PowerPoint, which they noted will be the wave of the future in terms of making presentations, both because of its ease of use as well as its graphics capabilities. (The presentation will be attached if permission is granted.)

Together, all four students noted what makes a lab good or bad. Their insights are shown below.

What makes a lab worth doing?

One student pointed out that labs with living organisms are good, since he wants to be a doctor. Overall, though, the students agreed on key characteristics that make a lab useful:

- The lab has activities that are used in real life outside of the classroom.
- You understand what you are trying to accomplish; a great example was a five week program for gifted students where a moon rover was designed.
- The lab is interactive; an example was a real-life demonstration of the Hardy-Weinberg equation with students acting out the individual parts. Hands-on labs are thus a plus.
- Things that blow up with chemicals! (especially for younger students or those who were not initially interested in science)

Additionally, how the lab is done affects its utility. For example, it is nice to have enough time to do it right. As in the real world, not everything will always work the way it should, hence students should be able to explain why things don't work instead of simply having to do the lab over multiple times. For example, students could be asked to describe the types of experimental error (misuse of equipment, calibration error, or equipment failure). Good teachers will take advantage of this and take pressure off to get only the "correct" results.

What doesn't work?

One student mentioned "I'm not really a lab person" but again, all four were able to agree on some characteristics that can kill a lab:

- Labs that are process-oriented or packaged too much. If you can't stray beyond the borders, it is going to be boring.
- The plant transpiration-rates lab was useless, in part because nothing ever happened but also in part because one had to redo it several times. Other pointless or repetitious labs that were mentioned included the pendulum lab, scale drawings, and the human physiology/tissue lab.
- Labs where you don't need to do anything to know what results you should obtain. Up until about 9th grade, for example, one could read a lab, write the answers, then do the lab, and have the results be correct about 90% of the time!
- Not being able to visualize what is happening; one student cited this as a difficulty with understanding cells and DNA because he could not see what is going on.
- Labs where the equipment or the procedures do not work.

Again, one can kill a good lab by teaching it poorly: requiring students to get only "correct" results, making students do it again and again, and having so much procedure that the only way to do all the steps is to constantly be writing and working and thus, not have time for reflection. (At this point, the teacher did interject that one has to go by the data; honesty is crucial. A story in *Scientific American* emphasized this concept.)

Discussion of SOLs

The students brought up the topic of Senate Bill 300, noting "the less state legislature requirements, the better." Unfortunately, S.B. 300 goes in the opposite direction, mandating a course path by 8th grade and a career by 10th grade, which eliminates choices early. A good teacher will cover what is needed without something like S.B. 300. Additionally, state standardized tests take an entire week in April; these are something that, if you fail, the school then has you take a remedial course to pass. The remedial course teaches you nothing except to take the tests.

Principal from West Virginia School 1

FACTORS DETERMINING WHETHER AN EDUCATIONAL ACTIVITY IS TO BE USED

To determine whether or not an activity will be useful, one must consider three criteria:

- *How does it affect every other program in the school?* Consider the example of the science department.
- Does the activity have the *full support of the Department Chair*?
- Is the activity both *academically feasible* and *academically challenging*? By this, we mean two things. First, the activity must fit within the schedule of the high school and mesh well with its philosophy. Second, note that students are diverse: some are highly motivated and others are less academic. For all students, however, the activity should be both interesting and challenging; there are high expectations for all students.

Additionally, the school would like to emphasize *problem-solving skills*. Whether this is a science or physics class, students need to be able to think on their feet. Characteristics of problem-solving skills are that they are lab-oriented (e.g. students must figure out how to move from one step to the next) and they require thinking beyond more than just a couple of steps. For example, one can read a novel and ask "what are the characters thinking?" This is far better than limiting the discussion to a rote question such as "who are the main characters?"

INSTITUTIONAL CONSIDERATIONS

- One must always consider *cost*, which is a big factor. Alternate funding sources should be considered.
- One must ensure there is adequate time to offer anything "extra". *State standards* have to be met. Senate Bill 300 requires that students statewide pick a "career major" such as college, health, etc. This will affect students' course selection as early as the 8th grade.
- All PCs in the school are networked, and support is being given to the "success" Lab. This computer lab is earmarked for use by the English Department for a certain number of minutes per day. Additionally, the school has placed five PCs in each social studies classroom. Technology coordinators are helping to show how to use this equipment.
- It may be hard to meet the requirement that TRAC must be used a minimum number of times per year.

Teacher from West Virginia School 2

BACKGROUND INFORMATION

The purpose of this series of questions is to get some normative information about the teacher and TRAC usage, including how often TRAC is used, what type of support is received from state or national centers, and participation in other programs. Portions of this interview occurred with the teacher and West Virginia TRAC Director Mr. Hazel together.[*]

- This teacher also has previous work experience with the West Virginia Department of Highways (DOH). At one point, he acted as liaison between the U.S. Bureau of Public Roads [precursor to U.S. DOT] and DOH. Later, he worked with both concrete and asphalt plants.

- The class in which the PAC is used (general physics) has a mix of students who are taking the class as their science elective. While PAC materials are used in accordance with the regular curriculum, this is not a TRAC PAC course per se. This is his third year with TRAC.

- The teacher has 34 years of experience, and is one of the few teachers remaining who is eligible to teach both chemistry and physics. Newer teachers must have a major in a subject to teach it; so theoretically, to teach those two subjects a volunteer would have to have had a double major in college.

- This is a rural high school situated in a depressed area where few professionals live. There is a huge gap between the gifted students and the non-gifted students, and that gap has widened as people have left the county.

- The first year the volunteer was fairly active, with the teacher and the volunteer doing the training together, and the volunteer did a couple of experiments pertaining to momentum and force. The second year the volunteer did not visit, but the teacher points out that that was not the fault of the volunteer. This third year the volunteer has already come and spoken with the students. The teacher feels that the volunteer's experiences are an important part of the TRAC process.

- The teacher noted that most of what he knows about the PAC modules was learned from the training sessions; in fact, any new modules or activities that should be used should be provided to teachers in a training session.

- The teacher did note the existence of at least one other career-oriented program: visits from DeVry and the Pittsburgh Aeronautics Institute, which are trying to attract graduates to their respective schools.

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

Overall, the teacher noted that it takes a while to set up PAC experiments, and that one has to set them up in advance. In general, he finds himself patching a lot of materials together to make the experiments successful: for example, in using the force module, he has to brace the force probe with C-clamps (not part of the PAC) in order to show impulse and momentum to be the same (as described below).

The **motion fundamentals** module has been used. There was not a lot of success with the accelerometer, yet the idea of integration – finding the area under the curve – really seemed to impress the students as they can visualize the relevant mathematics. The motion detector, though, simply is not precise enough and will not work unless you have a 3-inch by 5-inch card [to restrict the field of view].

[*] Not his real name.

The **force probe** worked well once it was calibrated – and it must be calibrated – but the teacher used it in a different manner from the PAC activity: two photogates are used to compute the velocity of a car, and then the theoretical impulse as deduced from "impulse = mass * velocity" is compared against the actual value as measured by the force probe, and students can see the sine wave that results. This module fits into the curriculum in the second semester, hence it has not been used yet for this year.

PC-Solve has been attempted a bit; the calculus students have used it sporadically as a tutorial. The vectors have been used in an honors class; the students liked the vector program because it was so visually oriented: the vector components portion was useful as well. In short, if the teacher sees a set of materials and thinks he can make things easier, then he will use it.

The **Sound** module has not impressed the teacher, but the equipment has been used in the past in conjunction with an experiment on resonance. Sometimes the equipment works and sometimes it does not.

The **Maglev** module is well liked by the students and is the teacher's favorite. The teacher likes the creative aspects of the module, as well as its quantitative aspects. The students also get to see the relationship between mass and acceleration in the real world. Interestingly, the teacher and the students had no trouble with the interlocking magnetic strips [whereas other schools in the interviewers' experience had had difficulties]. The teacher pointed out that in this case, the students understand what they are doing, and in that situation they are eager to solve problems that arise. By contrast, in a chemistry experiment (where one cannot visualize the results), if there is a problem then often the student is lost. In general, though, honors students will want to know more than regular students.

SimCity was used only during the first two years; it has not yet been used much this year. Students became addicted to it! (It has been used by several students, although this teacher does not encourage its use.)

BridgeBuilder is something that the teacher would like to use more in the future.

The **two videos** are not very useful: the one regarding the PAC itself does not show a lot of development in the transportation field.

The **manuals** are not used by the students: instead, the teacher's experience have led him to devise a procedure where the students devise the lab and take ownership of it. In this vein, he talks to the class as a whole, soliciting ideas from them regarding

-- what is the problem we are trying to solve?
-- how will we solve the problem? (This is a brainstorming exercise where several possibilities are considered.)
-- what experimental procedure should we now follow?

Then, the teacher types up a lab based on what the students have said in class. In short, the same subject may have a varying procedure from year to year based on what the students say in class that particular year. The teacher points out that "for whatever reason" the students seem more motivated to do a lab in this fashion rather than doing it straight out of a book.

Finally, the teacher notes that when it comes to reusable materials, more copies of Bridge Builder and the manuals are needed, as well as additional magnetic stripping which is hard to obtain.

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

What works?

The teacher pointed out that materials are supplemental, and are there to help the students. They really enjoy, however, the design aspects of the lab. This teacher's advice is broken into two categories: specific examples of activities that have worked well and general characteristics of successful activities.

Specific Examples of Activities That Work:

- *Wave modeling*. Students are very interested in the behavior of waves, whether we are talking about light or sound. A way to capture this interest is through the use of a ripple tank, which involves filling a basin with water; the students can then visually observe refraction as well as how the water affects the wave's behavior. (The concept of interference is not intuitive to the students, but the wave tank helps them to visualize it.) They can also measure the speed of the wave.

- *The "cube" experiment*. Courtesy of Ms. Green, West Virginia Department of Education, the students used four 3-inch by 5-inch cards to design a cube and then compete to see whose cube can withstand more weight (one held 24 pounds before it was crushed). This activity has been very successful.

- *Bottle rockets powered by baking soda and vinegar.* The amount of thrust is controlled by limiting the amount of one or the other component.

- *Other*. It should be noted that this teacher mentioned several other ideas for physics experiments that have been used to garner students' attention, and while it was impossible to record each of these ideas in sufficient detail here, it serves as a reminder that there are good ideas available.

Characteristics of Activities that Work

- *Have the students make predictions*. As part of the wave exercise, the students make predictions and then create an experiment that tests this prediction. They are taught that a good model will not only support what you see but it will also make sound predictions as well. In this case, the students will come up with all sorts of ways to get around the interference problem, including the use of slits to guide the light. The important feature here is to let the students tackle the experimental design portions without having vocabulary get in the way.

- *Do not present science as a set of expectations*. Today, students often believe learning entails simply showing up for class, but one needs to convey the idea that they need to "learn how to learn" or "teach how to think." Certainly content is important, but of greater importance is *how* to do science. One way to make this happen is the "black box experiment" where the teacher builds a black box without telling the students what is inside. They then they look at, lift, feel, and move the box, discussing the similarities and differences between their groups' boxes. They then develop a model to describe what is going on inside. The trick, however, is that the teacher never – even when the experiment is all done – allows the students to open the boxes. This conveys more strongly than words some of the openness of science; for example, the teacher asks the students "Now, can you imagine Bohr's frustration at not being able to open the atom?" Some students get so into this that they rip open the box anyhow, but the idea is driven home nonetheless.

- *Teach science to younger students*. The science club adopts an elementary school each year and works with the 6th graders in groups of 5. The high school students design an experiment that they will do with the 6th graders (e.g. the egg drop activity). The students put on a picnic for the 6th graders where they do five activities. The high school student mentor the 6th graders and judge the five events. This promotes leadership among the older students and does wonders for the elementary school students as well.

- *Recall that less is more*. It's more important to see something through to completion than it is to complete a bunch of activities. When students do not get good data, they sometimes get frustrated but more often they simply don't worry about it. In those cases a teacher has to ask them "why did this happen?" and then modify the experiments accordingly.

- [*Tailor material to the ability of the students.*] With the honors students, the teacher mentioned he is more concerned with the math; with regular students, his concern is more in the creative aspects of the modules.

What Does Not Work?

- *Most trouble starts with lecturing*: if that is how students are to acquire the bulk of the information in the class, then the teacher is in trouble! Some other problem areas were also given.

- [*Not knowing how well an experiment will work may cause problems.*]

  -- One activity that would not work would be to simply have students do computations based on the ideal gas laws [e.g. (Pressure)*(Volume) = (number of moles)*(R-constant)*(Temperature)]. Since some of the liquids won't vaporize totally, good results are hard to obtain; the same principle applies with other chemical reactions: some reactions are more complete than others.

  -- Another piece of advice is not to use paper tape timers and ticker tape to explain Newton's laws: the equipment simply does not work well enough to get accurate measurements. By contrast, the air track, acquired for about $600, has reduced friction such that one can really see the concept of inertia.

What is the ideal group size?

The air track activity above requires the use of rotations: in the honors class, where there are 15 students, groups of 5 students at a time will rotate through this station to learn concepts relating to force, friction, mass, speed, and Newton's law. The group of five is by necessity: the ideal group size will vary by activity: for Bridge Builder, groups of 1-2 students are ideal; for building Maglev cars, groups of 2 are ideal, and for testing the cars, groups of 8 to 10 students are ideal.

How would you teach elementary school students? (This teacher in particular has some plans to do further work with elementary school students in the future. Given his interests, he was asked for ideas on how to teach science to these younger students.)

One should consider the elementary school teacher's needs: that teacher needs a science background, an understanding of the scientific method, and knowledge of what one should do with the data that are collected. Let the content evolve from that. First, let the students ask questions on what interests them: if they talk about radon gas, for example, there are all sorts of questions pertaining to biology, chemistry, and physiology that may arise. Then, let the students design an experiment that aims to answer their question. Don not worry about how simple the experiment is, and do not worry if the experiment does not answer all of the questions. The point is to get students used to thinking about how to think.

If there had to be a choice between having an activity be high-tech or having it be interactive, it would be more important, all things being equal, for the activity to be hands-on. A lot of the time, high-tech work involves number crunching. The teacher views his job as being to teach the students to be able to formulate problems, and then to worry about the number crunching later on. For example, one activity entails placing a rubber-band powered car on a piece of board. The teacher then asks "how does the amount of the mass affect the distance the car travels?" Then, using Newton's law, students learn about how the relationship "Force = mass X acceleration" entails two inversely proportional quantities (mass and acceleration) given a constant force. This is an example of the constructionivist learning principle.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

The primary set of SOLs that is of interest in this case is the CATS standards (Coordinated and Thematic Sciences), a program sponsored by the West Virginia Department of Education, and similar in concept to both Goals 2001 and the CORD programs. The program was developed under a $5.5 million grant from the Natural Sciences Foundation. As explained by the Website found at http://www.wveis.k12.wv.us/cats/science/ on December 17, this program seeks to move West Virginia's science program away from the traditional "layer cake" curriculum, where the sciences are each taught as individual and mutually exclusive disciplines. At the time of the interview, the teacher explained that CATS entails a multidisciplinary approach, that seeks to integrate the sciences by teaching the chemical, biological, and physical properties of a theme or concept at the same time. For instance, using radon gas as the theme, there are chemical, physiological, and geological aspects that can be used to present the integration of the sciences.

According to the teacher, TRAC fits in well with the CATS SOLs. For example, the SOL "being able to visualize and construct an experiment" entails skills such as drawing and interpreting a graph and understanding the history of science (including early developments in transportation). Note that the school has a "success lab" consisting of 40 networked PCs that have Internet access, word processing, and graphing. Each student can open his or her own account if necessary. Eventually these students will be able to access their own work electronically; the school is awaiting Ethernet cards for this capability.

When asked, the teacher did point out that the PAC could be encouraged through illustrating how it could help teachers meet state standards. He felt that new teachers especially would be more likely to use TRAC if they had help in assessing which SOLs TRAC activities meet.

IDEAS FOR FUTURE PAC MODULES

- *Relate design to consequences.* Why must the bridge deck be uniform with respect to moisture? What will happen [to the design life] if the deck is not uniform?

- *Compressive cylinder strength*. Find some way of breaking cylinders, and relate different ratios of the aggregate to the compressive strength or the liquid limit. On the same topic, one could look at the geology of the area and ask why the road was not built.

- Make the *software more accessible* to the students (e.g. through a networked version of site-licensed Bridge Builder).

- *Provide training* for all of the modules, including Bridge Builder and SimCity.

- Use *graphing calculators* (e.g. the TI-83 or TI-85) which the students now buy themselves or which are supplied in the calculus class if necessary.

- *Bring in pre-service (college age) volunteers*, who are likely to have a contagious enthusiasm and who can show students the link between high school and college courses, yet who can also bring back to students the fact that they are excited about their college work. One alumnus who is currently in the honors program at West Virginia University returned to the high school and gave an excellent presentation.

- *Reduce the setup time.* The first time an experiment is attempted, a large amount of time is required just to determine the best arrangement. Once this is known, though, the teacher must still allow some time before every experiment to set it up properly.

- Put *useful lessons on the Web*. The website could have a lot of the non-PAC but useful transportation topics that teachers could use in the classroom. Along these same lines, it would be useful to have a special committee linking TRAC jr. and sr. high school teachers; a Website or newsgroup could be set up to this effect.

West Virginia TRAC Director

The interviews with volunteers focuses on two areas: (1) whether there are civil engineering or transportation components not covered by the modules and (2) identifying the salient features of the modules that teachers find useful. As the director of West Virginia's TRAC program, this individual was able to offer insights into TRAC training and policy issues as well. Portions of this interview occurred with the director and the teacher together. Another volunteer later helped clarify portions of this interview.

BACKGROUND INFORMATION FOR THE VOLUNTEER

The purpose of this series of questions is to get some normative information about the volunteers, understand their role within the TRAC program, and learn their expectations of teachers within the program. In this case, though, the Director was able to give a perspective on the program in West Virginia as a whole.

- *Training* has been done very well and has entered its third year. Their first year, they realized that one day of training was insufficient. The second year, they tried two days, which still was not enough. Training is now three days and involves the Department of Education (DOE) as well; at the most recent training, the teachers were broken into groups and worked with the volunteers. Furthermore, there is now a direct link between TRAC, the standards of learning (SOLs) and DOE. The state DOE coordinator (Ms. Green) went through the PAC and linked each PAC module to the West Virginia SOLs. Now that the teachers can see this linkage, they can tell how the PAC will help them and are more willing to learn to use it in the classroom.

- New schools are being added to the West Virginia program; 22 new schools were added this year and ten additional schools from Pennsylvania participated in the training, since that state's TRAC director is new and requested assistance from West Virginia's program. *Facilitation for teachers to attend training came from strong coordination between DOH and DOE*; in this case, DOE could pay the teachers' salaries for three days in the summer to attend training, with the engineers being there for a day. This helps get the PACs into the classroom. *Ms. Brown later clarified that facilitation for Pennsylvania representatives to attend training, however, came strictly from WVU.*

- The *qualities of an ideal volunteer* includes someone who likes kids, is energetic, and is excited about their profession. Mr. Hazel gave an example: a grandmother of eight who recently graduated with an engineering degree and had already visited her school four or five times. She was on a mission to share her love for the profession. However, it should be noted that there are non-engineers working in transportation, and West Virginia volunteers don't have to be engineers or even DOH employees: consulting firms and the Army Corps of Engineers also provide volunteers. Currently there are approximately 50 volunteers in the state.

- *Minimum expectations of the volunteer* have been outlined as four visits per year to the classroom. In the *first visit*, the volunteer functions as a teacher's aide only: she or he is not on the "hot seat". The reason for this first visit is twofold: first, to make the volunteer more comfortable (e.g. see the classroom setting, know how to get to the school, and know where to park) and second, to make the teacher more at ease with the volunteer (in this case, the teacher can show off his class). In the *second visit*, the volunteer describes engineering as a career field. In the *third visit*, the volunteer helps the teacher with a PAC activity, and in the *fourth visit*, the volunteer leads the class on a field trip (e.g. to see a road widening project, bridge construction, etc.). Keep in mind that these are minimums; volunteers may come more often, of course, and they are encouraged to interest the students in local issues (e.g. in this particular school, the volunteer might ask what W.Va. DOH might do to relieve congestion at school ending times.

- Note that the state is planning to conduct a spring technical conference, involving teachers and volunteers over spring break. Ms. Brown clarified that this is formally titled a *Spring Technical Conference for the Technology Students Association* (TSA) that is overseen by Ms. Green.

WHAT IS TRAC's MISSION?

In this state, TRAC's mission is "to increase interest and awareness in transportation-related careers, especially civil engineering, and to encourage students to purse higher education for those careers." The focus is not exclusively on engineers; DOH, for example, as a major employer has just 360 engineers out of 5,000 employees. There is also strong coordination between TRAC and West Virginia State College, a historically minority-oriented school.

Since this is an AASHTO program, support for the PAC comes from DOH management. The DOH Commissioner was originally approached by AASHTO personnel and liked the TRAC presentation. He made it DOH policy to pay for the employees' time, their use of state car, and their overtime for any training they might take. This combined with high teacher motivation helps the TRAC program. DOH believes that as it is one of the largest employers in the state, it should give something to the teachers from the transportation field; it also brings in engineers beyond those in the civil field. Additionally, DOE's participation has helped TRAC reach teachers and schools. The DOE coordinator noted that the program seemed not to have been developed with help from educators, and her involvement has helped to make TRAC more teacher friendly.

Regarding *quantifying TRAC's success*, Mr. Hazel mentioned Eleanor Brown, who is formulating a database that follows where TRAC students go after they leave high school. Right now the focus of that database is on civil engineers. At this time, she has sent 42 freshman engineering students from schools that had TRAC in 1997 a questionnaire and obtained two responses. (Note that just because a school participated in TRAC does not mean that a student participated in TRAC; hence some of these 42 students may never have been TRAC participants.)

OTHER INSTRUCTIONAL AIDS BESIDES THE PAC THAT HAVE BEEN USED

The TRAC PAC is one type of instructional aid, but teachers have experience with other aids such as computer simulations, role playing, games, demonstrations, or experiments. Successes and failures from these other types of aids ***besides*** *the PAC may illustrate what the TRAC PAC should ideally accomplish. In short, what are the characteristics of an instructional aid that make a teacher use it over and over again?*

The PAC needs better, more user friendly materials, and it needs a tighter link with the SOLs that are required by teachers. Consider the following examples that illustrate potential PAC improvements:

- Additional contributions have been made by Ms. Green; the cube box activity (mentioned by the teacher) is just one example. Other examples include math modeling with "ModelSmart", a more advanced version of Bridge Builder. It differs in that one can design a "software" bridge made out of locally available materials, such as balsa wood. With this package, one can design a bridge and then immediately build it and do destructive testing.

- *Add new PAC modules* that would involve topics such as GPS, surveying, or locks and dams. Some volunteers have been using non-PAC equipment, such as GPS, that is used in their work.

- Consider that we're in junior high schools and senior high schools: one should be asking whether the PAC is too high or too low in terms of *level of difficulty*. This state's technical schools have transportation as one of their career rotations; perhaps a version of TRAC should be available there.

TRAC POLICY OPTIONS

Several changes to how the PAC is implemented were also suggested. While these still concern specific PAC modules, they also affect how the PAC is delivered into the classrooms and how it is used by DOH.

- Consider a *speakers' bureau*, where persons, especially engineers from other disciplines (e.g. materials and mechanical) could give lectures on topics of interest.

- *Consider where we are headed [regarding procurement]*. The director pointed out that TRAC will not be long-lived in West Virginia in its current form for two reasons. *First*, DOH cannot legally purchase computers and then give them to schools. This means that the education community has to buy into the program enough to purchase the equipment and believe in it, and that is not currently the norm. *Second*, DOH – or a school – can buy these materials more cheaply from suppliers directly (such as Vernier) than they can from TRAC, especially when one considers that teachers often get discounts from their professional associations. One cannot tie the schools into spending more money than they have to. In fact, recently DOH (by law) had to procure some additional probes from Vernier because of low bid rules. In this sense, it hurts the TRAC program that the PAC is purchased not directly from suppliers but instead through a middleman, raising prices by about 10%. (The director also points out that teachers don't really need the case that the materials all come in, nor do they need all the materials lumped together in a single unit. If one looks at the catalogs that teachers have available to them, one quickly sees that there are a lot of options for materials, and word-of-mouth is the way many teachers find out about a potential activity.)

- [*Recall TRAC's strengths*]. TRAC has three characteristics that other [off-the-shelf] activities do not have: (1) the services of volunteers, (2) the provision of training with the activities, and (3) the backing of DOE.

- *Put this in a teacher friendly format.* This means moving away from lumping everything together in a single PAC. Going beyond the $12,500 participation fee, a school pays approximately $1,199 for a PAC, yet one could probably buy the individual PAC materials for about $600. Additionally, these individual modules should be simple things that teachers can "plug and play". Finally, see what else is available [that is low cost, simple to use, yet of interest to students].

- *Consider the use of graphing calculators*. The TI-83 and TI-85 calculators are provided by the schools, and these process data just like the more expensive PCs.

Volunteer from West Virginia University

BACKGROUND INFORMATION

The interviews with typically facilitators focuses on two areas: (1) whether there are civil engineering or transportation components not covered by the modules and (2) identifying the salient features of the modules that teachers find useful. In this particular case, though, the volunteer was interviewed because of her affiliation with West Virginia's TRAC program, including her work with coordinating the program and her interest in tracking former TRAC students. The TRAC director was on hand to answer the question pertaining to selection of schools and coordination with DOE, although both individuals recommended talking to the DOE representative for additional information pertaining to DOE's involvement.

Ms. Brown's* involvement with TRAC began through WVU: about three years ago, WVU became involved with the TRAC program but no funding was available for a separate TRAC position. Therefore WVU simply added the TRAC duties to the duties of the WVU Freshman Coordinator at the time, without according that person additional funding. At this same time, the first TRAC conference in Minneapolis was held, and the Coordinator was unable to attend as she was on travel; hence Ms. Brown went in her place simply to gather information from the conference and report back to the Coordinator.

Ms. Brown was impressed with the training session and the people at the national conference and realized she might be able to provide some assistance through her work at WVU. After the conference, Ms. Brown, her boss at WVU, the West Virginia TRAC Regional Center Director at the time and the current DOH head of Human Resources, and the coordinator discussed the selection of schools for West Virginia. Originally, ten schools were selected: five that had expressed an interest and five that were recruited by the TRAC team based on minority representation and geographic location. In February of 1997, training was conducted by Gary Hazel and the coordinator within West Virginia. Soon thereafter, Ms. Brown replaced the former freshman coordinator as the WVU TRAC liaison, and now she and Mr. Hazel work together; he manages the West Virginia TRAC program overall and she oversees WVU's role.

THE ROLE OF THE UNIVERSITY

WVU has three specific interests in the TRAC program:

- *Arousing student interest in engineering or college attendance*. The state's rate of college attendance is not very high, and WVU would like to raise that.
- *Preparing secondary school students for the college engineering program*, since the course of study for engineers is quite demanding.
- *Making college graduates ready to contribute to the workforce* – this is a goal both for DOH and the state as a whole.

To achieve these goals, WVU seeks to provide volunteers and to provide training. WVU's two volunteers are the Director of the Technology Transfer Center and an engineering instructor at Fairmont State University (which has a partnership arrangement with WVU). The former volunteer actually works with a middle school; both volunteers are very outgoing and bring skills to the program that other volunteers may not have, such as an emphasis on public relations. While DOH gives time off and/or extra pay for its volunteers to work in the schools, WVU's volunteers simply donate their time to this effort.

WVU's main contribution is the WVU TRAC Coordinator (Ms. Brown) who develops and conducts training with the other two participating agencies (DOH via Mr. Hazel and DOE via Ms. Green), developed the

* Not her real name.

database of TRAC students, developed the CareerTRAC Scholarship Program with Mr. Hazel, and is conducting the only program evaluation/research project in the state. Ms. Brown notes that a portion of her training consists of the ITS, Sound, and SimCity modules. Regarding ITS, she notes that the specific ITS activity is too simplistic to be used even at the intermediate school level; it is briefly covered at the training but rarely will students do it more than once. Instead, what works is to show the ITS video and discuss ITS applications and research.

SELECTION OF SCHOOLS

At this point, Mr. Hazel explained the selection of schools in West Virginia, acknowledging that when he came on board, there were already some schools that were part of the TRAC program. Shortly after he started working with West Virginia TRAC, the Department of Education's (DOE) Ms. Green also became involved with TRAC. The reason was that DOE administrators considered the TRAC program and the Federally funded School-to-Work program to be related. DOE and DOH arranged for the Federal grants to fund purchases of the PAC, since the School-to-Work program had approximately nine functional areas they wanted to get into the schools, one of which was engineering. Under this arrangement, DOE solicits a larger number of schools from those eligible for School-to-Work funding and then DOH has selects some of these schools that would receive the PAC. Out of the 30 candidate schools submitted this year, the DOH chose 20 to participate.

Note, therefore, the schools pay for the PAC through grants from the Federal program; typically a school would get a $2,000 grant, with $1,200 being used to pay for the PAC and the remainder being used for training and supplies for other educational activities. The school is required to have a suitable computer on which the PAC software can operate; if this is not the case, then the school must upgrade or purchase the necessary computer. There is a School-to-Work coordinator in each county; in fact, Mr. Hazel notes that having the responsibility for tracking the PACs and software now rests with DOE rather than DOH, and the removal of this burden makes matters much easier.

When asked if there were any hidden difficulties with this DOE/DOH coordination, the Mr. Hazel identified one: *there must be a contact with the state's Department of Education to make this happen*. In his case, he was introduced to DOE representatives by a contact person he knew in the Governor's office. Obtaining this contact in other states can be difficult, but in his view, it is the only way in which the TRAC program has been sustained, at least within this particular state.

A PROGRAM TO TRACK FORMER STUDENTS

Ms. Brown has initiated an effort to assess TRAC's impact on former students, realizing that the this is West Virginia's third year and that out of the ten original schools, nine are still actively participating. Ms. Brown has identified 42 students who attended schools that had the PAC and who are currently enrolled as freshmen in WVU's engineering program; they are an even mixture of males and females. There are two limitations to this effort. *First*, not all 42 students necessarily saw the PAC as they may or may not have been in the particular high school classes that used the PAC. *Second*, the PAC may well have had an impact on other students besides the 42 WVU engineering freshmen, since the PAC was used in all sorts of high school classes (technology, physics, honors physics, and introduction to engineering), some of whose students may have been less likely to go to college or may have gone to colleges other than WVU.

A short survey was sent to the 42 students, asking them a few questions about the TRAC program. Two responses were obtained: one was a female student from John Marshall High School and one was another person who chose not to identify himself or herself (respondents had the choice of leaving their name off of the survey). A third person (not one of the 42), who is in his second year of engineering at WVU met Mr. Hazel and has also agreed to send in a response in the future. This student is in the "Co-op program" where he works alternating semesters for the DOH, thereby taking 5 years to graduate. Ms. Brown is also working in conjunction with DOE and DOH and their legal representatives to design a permission slip, for teachers' use, to be filled out when students enroll in TRAC.

Five questions were contained on the survey: (1) rate the TRAC program, (2) evaluate how much TRAC improved math and science education, (3) rate how well TRAC showed that the engineering profession is open to everyone, (4) rate how well TRAC introduced science and engineering concepts to high school students, and (5) did TRAC influence the student's decision to go into engineering? Both students, on a scale of 1 to 5 (where 5 is high) gave an answer of "4" to the first three questions. For the fourth question, the female noted TRAC did a very good job of introducing science and engineering concepts whereas the other student chose not to answer the question. The female did not answer the last question but the other student noted that TRAC "aroused his interest" in engineering. Ms. Brown noted that the female respondent did have a very high opinion of the Dave Goodwin (the teacher who used the PAC).

SPECIFIC TRAC MODULES THAT HAVE BEEN USED

This section typically outlines the current modules' strengths and weaknesses, including the utility of the instructor's manual and the student's guide.

Ms. Brown noted that it is very difficult to make blanket statements about which modules work and which ones do not, since her own impressions from the training are that there is such a wide range of teachers, curriculum needs, students, and classroom environments. It would take some type of questionnaire that asked teachers how often each type of module was used in order to obtain this information.

She was able to offer some initial impressions from the training, such as the observation that the sound module software is simply not that useful (although the meter for measuring sound is used by many teachers) and that teachers did value the graphing capabilities of the software. PC-Solve sparked some interest, and she was surprised by the large amount of interest science and math teachers had in the MPLI unit.

RELATIONSHIPS BETWEEN STANDARDS OF LEARNING (SOLs) and ACTIVITIES SUCH AS TRAC

SOLs are relevant but Ms. Brown suggested contacting Ms. Green for more information. One comment she did make was that teachers had told her that the graphing capabilities of the TRAC software helped get students up to speed on the skills needed to pass standardized tests.

IDEAS FOR FUTURE PAC MODULES

Three types of improvements are recommended for the PAC:

- *Use inexpensive hands-on activities* rather than computer software only. This is not to say that computer software does not have its place, but examples such as the "cube" [where students use index cards and tape to build a cube that can withstand the most weight] cost practically nothing, are very hands-on, and motivate the students. In fact, the use of more hands-on activities is desired by WVU engineering professors who feel that their students come to the program without this needed experience. In this sense "hands-on" does not mean a computer simulation. As an aside, the volunteers and teachers now meet early in the year to fill out and hand in a TRAC planning form, specifying the dates volunteers will come to classes and what activities will be done. A surprising number of schools plan to do the cube activity.

- *Use hand held calculators*, such as the TI-83, which will do just about everything in the current PAC. In fact, Texas Instruments (TI) has loaned WVU calculators and modules for short-term use in the classroom (e.g. training and demonstrations); TI has also provided grants to use this equipment. Some schools purchase these [graphing] calculators with School-to-Work funds not used for the PAC; these calculators are a great resource for accomplishing certain labs, especially in classrooms where there is only one PC. Using the graphing calculators allows all of the students to the lab simultaneously rather than having to do the lab as a demonstration because of limited numbers of computers and other TRAC equipment.

- *Coordinate TRAC with career outreach to minorities* as explained in the next section.

REACHING OUT TO WOMEN AND MINORITIES

Ms. Brown pointed out that there is a lot more the PAC could do to reach women and minorities. The caveat to this is that the grade level at which the PAC is used is relevant; the PAC needs to be used more at the middle school level where students have more choices and are not in a career or educational track yet. Specific suggestions for improving outreach are the following:

- *Have good role models visit the classroom*. For example, having an attractive female engineer discuss the PAC shows that not all engineers are “nerds” and, especially for women, that it can be “attractive” to be an engineer. Ms. Brown emphasized that it is important not to underestimate this presentation aspect.

- *Tie-in the math or science theory to the real-world activity more directly*. Students need to see that the math they are doing directly affects what they are doing in the real world.

- *Give students a mental “bridge”* from what they already understand to the new concept they are learning. There are often mental blocks to achieving math and science skills, and some of the scientific software reinforces this situation. Students need to know they are capable of using, for example, a transportation-related technology. Students are often impressed by the fact that the math they are doing in school is related to what engineers do in the real world to produce physical products. This connection, and a similar one in physics, needs to be made more solidly, especially in terms of African Americans and women.

- *Contact another teacher* (Patrick Durkin) who doing a great job using the TRAC materials in his various classrooms.

Volunteer from West Virginia School 2

The interviews with volunteers focuses on two areas: (1) whether there are civil engineering or transportation components not covered by the modules and (2) identifying the salient features of the modules that teachers find useful.

BACKGROUND INFORMATION FOR THE VOLUNTEER

The purpose of this series of questions is to get some normative information about the volunteers, understand their role within the TRAC program, and learn their expectations of teachers within the program.

- This is the volunteer's third year in the program, and it is also his third year with the same school. His first year he had three visits to the school, last year he had none, and this year he hopes to visit several times.
- The classes have been comprised of honors students – advanced chemistry and advanced physics. His visits show them the utility of problem solving.
- His first visit is typically a lecture describing the field of civil engineering, where he takes in plans and anything else that describes the field or will interest the students. Then he goes back if the teacher would like help with the experiments. He notes, though, that the students will go back and tinker with the experiments when he is not present.

GENERAL COMMENTS FROM THE VOLUNTEER

Overall, the modules in the PAC seem useful, but the equipment needs to be made much more reliable. One should be able to just "plug it in" and then be able to get the materials to work, whereas right now one has to tinker quite a bit. There are always problems with the hardware and the sensors (testers).

- The volunteer recalled that the motion fundamentals module (velocity) and the force module (impulse) have been used, whereas Bridge Builder and SimCity have not been used.
- In general, only people who are computer literate are capable of doing the modules, but this might be because of there being only one PC in the classroom. With 15 to 20 students in a class, it is tough for everyone to have a role.
- There is a success story: even though the probes generally need to be more reliable, and even though they didn't work during training, one bright student got the probes to work in the classroom.

Finally, the volunteer noted that it seems that only portions of the modules pertain to transportation, such as Maglev, Bridge Builder, and perhaps SimCity. One should consider adding CAD (computer aided design). This will get the students motivated, and more importantly, may attract students to the field of civil engineering. Keep in mind that the transportation field is competing for that type of student (e.g. who likes CAD) against other fields, such as computer science: if students realize that civil engineering has neat high-tech stuff like that as well (e.g. being able to rotate an object 360 degrees on a screen) then more may come to the field. One could add to CAD module other components such as bridge design or finding the quickest route between two points.

Students from West Virginia School 2

The interviewers spent approximately 25 minutes talking with general physics students about what they thought was entailed in the various aspects of transportation. Students offered their own ideas of items that are transportation related, such as congestion that occurs when school lets out, an exit that is so close to a tunnel that it can cause a bit of a hazard, unfriendly truck drivers, rerouting traffic, ramps, road rage, and air pollution. Then the interviewers wrote some of these ideas on the blackboard, along with some of the PAC modules.

Students recalled five transportation related activities that they had done: the cube problem, Maglev, SimCity, "moving things" [their term for the motion module], and Bridge Builder. The end result of this 25 minute period is that one could see two columns on the blackboard: the PAC modules that had been done and the transportation-related problems that came to mind. In comparing the various activities, many students liked Maglev the best. They were amazed that the cars actually floated with the magnets. They also liked that fact that Maglev trains already existed. They liked the cube second-best, and they thought the motion module was the worst – they couldn't get it to work and could not figure out how it related to transportation. Except for the motion module, though, some students did not really have strong opinions about which of the remaining four (Maglev, cube, SimCity, and Bridge Builder) was the best or the worst: in fact, one student stated "We should be doing more stuff like that."

The interviewer than asked the students to develop their own transportation-related activity in groups of 3 to 5 people. Students wrote or drew pictures on flip charts with magic markers, and then there was enough time at the end of this for some of the students to present their work. Here are their activities that may be suitable for addition to the PAC.

Group 1: Transportation Diorama (our title), 3D attachment

These students were original in that they were the only ones to build an actual 3D model. The students drew a busy road and showed pedestrians trying to get across. They then built an actual pedestrian overpass over the bridge. (Unfortunately, this prop was used by a guest speaker from the Pittsburgh Aeronautics Institute so the interviewers could not take it with them, but it would be wonderful if those three students could add any information necessary to this description).

Group 2: G.P.S. (drawing attached).

"Students stand around a central location of a fixed object." This group explained aloud a "trick" to this activity: only one person at a time has the honing device (in this case, a GPS [global positioning system] receiver). The students have to work together to find the object or find their way out of a maze.

Group 3: Eggcelerated Impact Experiment (drawing attached)

1. Objective is to create a vehicle that can hold an egg and be launched into a wall without breaking the egg.

2. Try to find which design of car has the greatest stability.

3. The car that can hit the wall with the greatest velocity and still keep the egg from breaking winds.

4. You will find in this experiment how different designs can stand up in a crash test.
   Syam, Joe, Josh, Jason, Levi

Group 4: Design Your Own Boat (drawing attached)

Purpose: Using a piece of Styrofoam, design a boat focusing on efficiency rate and water displacement.

Group 5: Use SimCity to create more efficient traffic patterns (drawing attached)

“Computer simulation program that deals w/ trans systems. Program creates cities w/traffic problems. Objective: create a better transportation system. Cities get increasingly difficult as students become more and more apt to fixing the problems. Things to add include off-ramps, bridges, stop-lights, airports, subways, trains, etc. City is considered to be “fixed” when there is ample transportation for all people in the city, and traffic runs smoothly. Also, after students can fix existing problems, they could be given a city with only buildings and no transportation systems. They could design completely all of the transportation for the city and the program could evaluate their system.”

The idea here is that while SimCity does have a “transportation” component, it does not realistically account for congestion. Either a new computer program or a major addition to SimCity would be required such that traffic could be generated and realistically simulated. One student from group 2 raised a question pertaining to this as well. [The interviewers noted that there are simulation models, such as Netsim, that are realistically used by transportation engineers for these types of traffic studies.]

Group 6: Accidents (our title) drawing attached

1. Go to DMV and get accident statistics that occurred in the last 5 years (all ages).
2. Create a pie chart demonstrating the # of accidents per age bracket.
3. Start in the Junior High teaching this stuff.
4. Show gruesome films show what happens in wrecks.
5. Breakdown each age group stressing that teens are generally accident prone.
6. Describe ways to prevent accidents (including wearing seat belts).
7. Test the kids to find out what they think.
8. Ask them questions like (what they would do prevent accidents) or (how they would be a better driver).
9. Allow kids to make rubbermade cars.
10. Let them beat the cars to see who could build the strongest design.

West Virginia Department of Education Representative

Previous conversations with West Virginia TRAC personnel showed a strong link between the West Virginia Department of Highways (DOH) and the West Virginia Department of Education (DOE). Ms. Green was able to offer views on the relevance of state standards of learning as well, the suitability of the PAC in the classroom, and lessons learned from the use of hands-on educational activities.*

How are the Technology SOLs used by teachers?

1. Consider the broad standard "Use oral, graphic, and written communication skills to effectively deliver a variety of messages" shown under "Foundations in Engineering." Within that standard are several specific tasks, one of which reads "FIE4: Prepare and deliver a 3-5 minute prepared speech on a given topic." Would teachers tend to focus more on the broad standard or the specific tasks?

    The broader statements are *goals* that teachers are held accountable for. The more specific statements are *objectives*, or examples of how teachers can meet the goals. The list of objectives is not exhaustive. The objectives give teachers guidelines on meeting goals. There is also a 330 page curriculum that covers the day by day lesson plans that can be used for 180 days (one hour per day) to teach the subject. There is also a curriculum for middle school technology education, called <u>Exploring Technology</u> which is based on rotations among 10 specified work stations. However, Technology Education is an elective, and as such, is not bound by standards. Even if it were, the only penalty for not following the standards would only be the withdrawal of vocational education funding of approximately $1.00 per student, which is not much of an incentive.

2. It does not seem that providing curricula (e.g. the 330 page curriculum just mentioned) to tie directly to the SOLs is the norm in other states. Are we mistaken?

    There are some other states that do tie curricula to SOLs; Minnesota is one and other states may be identified through the International Technology Education Association. She notes, though, that Virginia's actions in the past provided one example of what West Virginia did not want to do, which led to West Virginia's decision to create detailed SOLs and curricula for the technology course. In Virginia's case, [state DOE] personnel had given general guidelines and activities, but had provided no guidance as to how to deliver these concepts to teach students. The end result was that these ideas were simply not used. West Virginia chose to bypass that problem through its development of the detailed technology SOLs and curricula; in fact, the SOLs were developed in conjunction with specific lesson plans and equipment for the various workstations in the classroom.

How current are these particular standards?

1. How long have they been in use?

    The basic four-part standards (communication, construction, manufacturing, and transportation systems) were developed in 1985 and have been in place for 13 years. The recently-added Foundations in Engineering standards have been in use for 3 years. There have been vocational education standards in WV that were the basis for outcome-based education and assessment for 20 years or longer. The academic subjects in WV have been taking this approach for only about 2 years.

2. Is there some sort of implementation guide for teachers? (something that would show them how to go from the SOLs to actual lesson plans, or what "counts" as an implementation?)

    The objectives contained in the SOLs provide guidance, and curriculum guides provide specific lessons and activities.

* Not her real name.

How does TRAC fit into the West Virginia SOLs?

1. What has been your impression of how easy or hard it was to relate the PAC to the standards?

    It was Ms. Green's opinion that some TRAC activities fit in with the SOLs and some don't. Many of the technology teachers have been using similar activities for years. Her comments on the various modules follows:

    Bridge Builder: TRAC is generally weak in hands-on activities. For instance, Bridge Builder is a good piece of software, but it's just software and the students don't get any hands-on application experience. They come away without a clear understanding of tension and compression. West Virginia had supplemented this in several ways: they have activities, like using tongue depressors or balsa wood to build bridges and test for tension, compression, and efficiency. Instead of Bridge Builder, they use another piece of software, ModelSmart, from the same company. This program allows students to actually design and test their model wooden bridges with the software and then actually build their bridge. The engineers like this software as well, since the design data is very close to the actual data. This fits into the SOLs well, since one part of the Construction System curriculum is on heavy construction.

    Yellow Light Problem: Her teachers did not care for this activity, even after several attempts.

    MPLI activities (force, motion, temperature sensors): The physics teachers like these. However, many have graphing calculators that work with the CBLs. One benefit of the CBLs is that the students can use them to leave the classroom to collect data and return to analyze it.
    PCSolve: The teachers like the idea behind PCSolve, but don't like the software. It's an old DOS program that puts the students to sleep. A math reinforcement software, especially linked to engineering activities would be great.

    SimCity: Many teachers use this, but it takes a very good teacher to use it to actually teach specific engineering related lessons. However, teachers often use it as "filler" or as a reward, and let students work alone.

    ITS/Flow Chart: These two modules are good ideas, but their implementation is boring. There are very few choices and teachers complain that they're done in 5 minutes. This needs better software. They have been trying to tap into real time data from TMS centers, such as Seattle's TMS which makes video images available over the Web, and would like to be able to use this data.

    Maglev: Teachers in West Virginia have been doing a Maglev activity for years in the Technology Education program; the TRAC activity fits in really well. The WV activity is more true to life than the PAC's Maglev module, since they use potentiometers to vary electromagnets to pull the cars along rather than relying on gravity for forward movement.

3. Consider the broad standard "Understand and demonstrate knowledge and techniques about electronic control and use them to solve open-ended problems from a design brief." Again, within that standard are several specific tasks, such as "FIE52: Describe the purpose of input (sensing) devices such as switches, temperature, and light sensors and use them in control circuits." Would PAC experiments such as the motion fundamentals module meet this standard, and if so, is it more important to meet the standard at the broad level or the specific task level?

    Currently, teachers cover fundamentals of motion in the Transportation Systems curriculum in the Tech. Ed. Program. This includes such topics as propulsion, aerodynamic properties, and vehicle design. At the end of the unit, the students design cars and motion sensors are used during races to collect data on the cars' performance. The TRAC Motion Module could be used in this exercise.

4. Suppose a new PAC module was being developed – say, one that related to geometric design or surveying. Would it be more important for that module to be shown to relate to the broad standard ("Apply accurate measurement practices, solve math problems, and perform algebraic computations as they relate to transportation careers") or would it be better to tie the module directly to the specific tasks shown therein, such as "TRN9: Interpret various charts, graphs and drawings used to display numerical data."

    It would be better to tie TRAC into the goals, rather than the objectives, since the objectives are simply examples of how to put the goals into effect.

5. Everyone that we have spoken with [from West Virginia] has widely cited the Card Structure example. Given its success (and, we assume, the success of lots of other types of low-cost/no-cost lessons) do you see a role for the PAC in the future?)

    The Card Structure problem begins with an exercise where students test shapes (circle, triangle, square) to see which is strongest. Then they use this information to design and build an interior for the cube that will give it the best structural integrity. This activity is hands-on and very inexpensive. We use it as a substitute for another introductory activity listed in the TRAC guide. Also, since no computers are needed, the activity doesn't suffer from the problem of many of the TRAC activities -- the difficulty of doing the activity with only one computer when several are needed to accommodate several small lab groups. TRAC needs more activities that are not computer centered.

    There are an abundance of hands-on activities that are inexpensive. In fact, the reason West Virginia started using activities like the "cube" is that back in 1987 the state wanted to start converting shop-oriented/woodworking classes to a technology-based curriculum. Teachers needed activities to teach these new concepts that were low or no cost and used locally available materials.

How do national standards affect state SOLs?

1. Was the National Council of Teachers of Mathematics (NCTM) or other national standard a big influence?

    In general, most states base about 80% of their state SOLs on national standards, at least in science and mathematics. Because of her familiarity with the creation of SOLs for technology education, the interviewee was able to recommend four additional persons to contact regarding SOL development.

2. What is the relevance of the "Stanford 9" to the mathematics SOLs.

    Ms. Green is not a mathematician, but she noted that the goals that are highlighted in boldface in the publications [available over the Web and entitled *Adolescent Mathematics Education* and *Adolescent Science Education*, respectively] corresponded with the Stanford 9, which West Virginia assesses in the 4^{th}, 8^{th}, and 11^{th} grades. The ones denoted with a diamond corresponded with the Workplace process Skills and Objectives, taken from the Secretary's Commission on Necessary Skills or SCANS Report. Many states use the SCANS report as a reference, although each state is different in the way they assess student progress.

What Would Influence Teachers to Move From "Tried and True" Activities to TRAC Activities?

1. Are there any topics in the Transportation Unit that teachers have had a hard time selecting activities for?

    For the most part, Ms. Green felt that there weren't any areas where *technology* teachers were having trouble finding good activities to meet the SOLs. Math and science teachers, however, are just beginning to encounter this challenge, due to the recent emphasis in those subjects on career exploration, as described below.

2. What would it take to get teachers to switch to a TRAC activity?

Most teachers are looking for *updated* activities that address their needs. They don't want “something else to teach” – they already have more than enough standards they have to meet – but they would rather have activities to help them teach what they already have to teach. They want something that is easy to deliver to the students that is also interesting.

Career exploration is a major topic in West Virginia now, since students are required to choose an area of career interest in school. Some of the academic teachers are floundering, asking themselves, “how do I take geometry, physics, or English and add career related information.” This may be way for the PAC to be used in the academic classes.

In addition, teachers are always looking for a “big ticket item” that they haven’t been able to afford on the school's budget. This may also be a selling point for TRAC. However, each teacher may be looking for a different big ticket item, so it is probably better to have variety in the PAC rather than just one expensive item. For instance, on the last day of TRAC training, the teachers were asked to pick a module that they would actually use in their classrooms and make a presentation to the engineer/volunteers. Each teacher picked a different activity, and the selection often depended on the subject taught by the teacher. For example, at one training session, no one selected the “town meeting” activity because there were no social studies teachers present.

Teachers also like it when all the materials and supplies they need for an activity is contained in one place, including refills. This may also be a selling point for TRAC. However, much of what is in the TRAC PAC (third party software, materials and equipment)can be purchased by teachers for much less than the PAC. For example, the blueboard can be purchased for about 8.00 for a 4’ x 8’ sheet; teachers don't want to purchase it from TRAC even if it means giving up the convenience of not having to make the trip.

Teachers do like getting materials, though, in addition to curricula: they probably could use something that was just curricula, but getting actual equipment and software that can be used (e.g. probes and such) – is a lot better!

One big criticism relating to the cost of the TRAC PAC is –the box!!!! It is huge, and filled with 12-14” of foam in the bottom to protect a few pieces of equipment in boxes. After teachers load the software and use the materials included, that expensive box is of no use AND ITS REALLY HEAVY TO TRANSPORT! (shipping charges??!!) Use a sturdy cardboard box that is designed with a handle to transport it. Save a <u>bunch</u> on the construction of the box itself, and shipping costs.

West Virginia currently stresses the integration of academic and technical education in their lesson plans. For instance, there is an English/construction lesson where an Elizabethan theatre is built. There are some other examples of this multidisciplinary focus.

It was also Ms. Green's opinion that TRAC has long needed the input of educators, and that if educators had been involved in the inception of TRAC, there would have been less “reinventing the wheel.” A lot of unnecessary money was spent, because the types of curriculum concepts and hands-on activities mentioned above have been taught by technology education teachers for 15 years or more, and TRAC was not aware of this curriculum area.

Finally, Ms. Green mentioned that the use of the engineer/volunteers was the really unique aspect of the TRAC program and that that could be in influential factor with teachers.

Supplement to the Interview

In conjunction with this interview, sample SOLs were obtained directly from Ms. Green, a representative of the West Virginia Department of Education.* These SOLs cover five specific technological areas: "Foundations In Engineering", "Communications Systems", "Construction Systems", "Manufacturing Systems", and "Transportation Systems." Within each area are approximately a dozen general principles and between 30 and 70 specific objectives. For example, within Foundations in Engineering, there is a general principle that reads:

> "Understand and demonstrate knowledge and techniques about electronic control and use them to solve open-ended problems from a design brief."
>
> Within that principle are several specific objectives, such as
>
> "FIE52: Describe the purpose of input (sensing) devices such as switches, temperature, and light sensors and use them in control circuits."

The DOE representative explained that the detailed objectives explain how the general principle may be applied; teachers may view the principle as an "umbrella" which they may meet by accomplishing via other objectives that the ones cited. This is especially evident in the transportation examples that are shown: for example, two general principles are given as

> "Apply accurate measurement practices, solve math problems, and perform algebraic computations as they relate to transportation careers", and
>
> "Apply design, creativity, and critical thinking skills to develop solutions to a variety of problems involving different technologies to meet specific criteria."

Within these principles are objectives such as

> "TRN9: Interpret various charts, graphs and drawings used to display numerical data", and
>
> "TRN11: Plan and select the materials, energy, tools, and processes needed for producing solutions to transportation problems, and produce solutions for a variety of problems."

* (unpublished data). Draft Technology Standards courtesy of the West Virginia Department of Education.

INDEPENDENT EDUCATOR EVALUATION

Teacher Michael Brittingham

Although Mr. Brittingham was involved with the research project from its inception, he also independently experimented with the PAC as a physics teacher with 29 years of experience. His findings, in his own words, are presented along with his recommendations, although headings have been added for clarification. This write-up differs from those shown previously in that it documents one teachers' perceptions as a result of trying most of the PAC activities on his own.

The TRAC PAC kit (hence referred to as PAC) was received on 1/15/99, whereupon I spent about a half hour reviewing its contents. A couple of days later I met with our Building Computer/Technology staff member to explain what I needed him to do in order for me to use the PAC with my classes. The PAC was a current version set to use a PC running Windows 95, with a CD drive, and an expansion bay for the interface module. Since our science department uses Macintosh computers exclusively, I had to arrange with him for the loan of a PC to use in my classroom. Although this shouldn't have taken long, we were in the middle of our exam schedule and the added issues of ending one semester and beginning another. After several reminders, the computer was finally set up to run the software and modules by 2/7/99. Unfortunately my normal schedule of activity would not permit me to fully begin investigation until Sunday 2/7/99, at which time I spent approximately four and one half hours on the task.

Videos

I began by watching the teacher video. This 10 minute long video was an introduction to TRAC PAC. It turns out to be a promo for 'why you should use TRAC PAC'. Besides not being particularly interesting, I found it to be even less useful. I had anticipated a 'How to' video that would help explain to a teacher how to get started using the kit and modules, not a justification for why the kit was developed. My recommendation here would be for a newer version of the kit, 'How to' videos be developed to supplement the teacher and/or student manuals. These videos would not have to be high dollar fancy films, but could be done cheaply and effectively to assist teachers with the implementation of the various modules. A general overview of how the material might be implemented into the curriculum could be followed by mini-films dedicated to each of the modules. I also found it interesting to note that in the beginning of this film, it showed and referred to a Macintosh computer as a part of the kit. I would be interested to know when, if ever, did they use Macs, and why did they change platform?

The second video I watched was the one for students. It was also about 10 minutes long, and promoted all forms of engineering. There may have been a few more images of civil engineering, but it did not dominate. Again, I did not find this to be a particularly motivating film. My recommendation would be to have this video aimed more toward the goals of civil engineering and in particular highway research, if that is indeed what TRAC PAC is geared to promote. It could also tie in how the activities of the PAC could be used to help give a feel for some of the activities handled by real engineers and engineering applications. Better still, develop a series of short videos to introduce each module that would help tie in each activity with its real world occupations and applications, as well as giving students an introduction on how to begin that particular module. This would be a far more interesting and intriguing way to begin a module than the student activity sheets which just sort of start them on the activity with words, no images, and no clear reasons why they are about to learn this material.

The video 'Moving Transportation into the Information Age' was a 12 minute video that dealt with the problems of maintaining the benefits of highway transportation for our children's future. The focus seemed to be on developing 'ITS' (intelligent transportation systems). The pitch of the film seemed to be toward a middle school audience, using student images and input mostly from the early teenage group. Some of the ideas presented regarding the use of sonar, global positioning devices, on board warning systems, interactive maps, etc. were excellent. However, I think at least for a high school market, they missed their mark. Again, why not show or refer to the motion detector module when talking about on board sonar and collision warning devices, as well as how some of the other activities and modules related directly to the real world and this quest for an intelligent highway system? I feel like it was the perfect missed opportunity.

PC-Solve

My next efforts were to actually try out a module. I suppose it might be beneficial at this point to clarify my background with working with these kinds of materials. I was approaching this with none of the TRAC PAC training and without the aid of a TRAC PAC volunteer, which I assume would have helped at least somewhat, although I gather that support system seems to have varied a great deal, based on reading the interview material from the various schools that have been visited. In the area of computers, I began with mainframe experience in engineering school, learning ALOGOL and FORTRAN as programming languages. With the development of microcomputers, I self taught myself BASIC, worked with early Radio Shack computers, progressed to Apple IIs, IBM DOS systems, Windows, and finally Macintosh. I have written software for commercial sale, taught BASIC programming, word processing, database and spreadsheet software to youth and adults as an instructor for the local community college. Finally, with a base degree in electrical engineering, I have taught math and physics for twenty-nine years in public schools. My teaching experience has including computers as well as using computer interface devices.

For my first attempt at PAC, I chose to look at Activity 1.2 which is the one on using PC Solve. Working in a Windows 95 environment, I double clicked on the PC Solve icon and was confronted with a selection screen the size of a three by five index card. Even my reading glasses had a tough time deciphering the choices before my eyes. I was finally able to figure out how to make the selection screen larger by some investigative trial and error, but not by any instructions that I could find written anywhere, PAC manual or booklet that came with the kit on PC Solve.

Following the directions in the PAC manual I tried to open the file indicated and continued to get an error message saying "Cannot open file for reading. Press any key to continue." After several attempts I realized I could not open any file at all without the same error message. Hence I chose the F1 key for help as indicated in the manual. This brought me two choices 'Welcome' or 'Change Directory'. Selecting either of these led to the same error message as before. Boy was I having fun! Assuming that maybe the Technology person who installed the software had made an error I decided to try to run the program from the PAC CD ROM. About 30 minutes later I finally seemed able to run the program from the CD without encountering the same error message. Progress at last!

Selecting and opening the file named in the TP manual, I was confronted with instructions to "Please enter the 1st and last name of person #1, person #2, section number, instructor's name, etc." Making up names and information, I continued on to read "Press any key to continue". Pressing any key to continue I kept looking at "Please enter.....". The only option that I seemed to be able to exercise was the choice to quit. All function keys, including the F1 for help did not work at all. Talk about user friendly! Even though the manual had forewarned me, It was also continually frustrating to not be able to use the mouse within this obviously older DOS piece of software.

Finally, I decided to just run a different file at random. This time I was able to get a true Help screen, which could be scrolled by arrow keys and selected by the Enter key. It became even more obvious how DOS-like this program was. The program also continued to refer to the calculator at the bottom of the screen, which never materialized regardless of how hard I tried to find it.

An hour later (due only to the tenacity of a bulldog) I finally got the desired file mentioned in the manual to open by telling it that I was Melissa Naidus (whoever she is or was). I was then able to open the second file suggested by opening one with a slightly different name of mathwsp.lib. This was the file I wanted that allowed me (and/or a student) to test your current level of math knowledge by choosing among 30 different topics. I tried four of topics. Not due to lack of any math knowledge, but instead due to the manner in which on screen instructions were given, I made initial errors in 3 out of 4. Apparently the program will keep track of your progress and success, which was beginning to make me look like a math idiot, although I have taught every level of high school math up through pre-calculus.

In all I spent over an hour and a half trying to figure out PC Solve, yet accomplishing only 4 of thirty topics in the first lesson. I feel confident that I could master this program given enough time, but why bother? My recommendation is that this piece of software be eliminated from the PAC kit. There must be better equation solving software out on the market. I know that many spreadsheet programs such as Excel or even the one in ClarisWorks will accomplish many of the same tasks that I see indicated. PC Solve is also supposed to graph (if you could ever figure out how to do it), but I could teach a student to graph in ClarisWorks or in Graphical Analysis (graphing software by Vernier that costs ~$40 for a building site license) in less that 15 minutes.

Sound and Motion Modules

Next I decided to try out some of the interface probes. Following the directions in the manual under Activity 1.2, I connected the interface box and microphone with the computer off to test the sound equipment.

The manual instructed me to open 'soundftt.exp' in order to check out the functioning of the microphone. Look as I may this file did not seem to exist. Hence I chose to open the file 'microphn.exp', thinking this must have something to due with the microphone. Sure enough, as soon as I opened this file, then I found the 'soundftt.exp' file (I know that even in windows files must follow DOS naming protocol, but couldn't they have done better than this?). After following instructions, and attempting several trials, I still had no data from the microphone. There were no hints available to indicate whether the fault was in the microphone, the interface box, the analog board in the computer, the software, or my own ineptitude. I decided to try another probe.

I replaced the microphone probe with a motion detector and the force probe and rebooted the computer. I was able to find the file indicated in the manual and watched the screen display data as if the motion probe was working. Trying to adjust the scales of the graph, it would not seem to plot velocity vs. time even though that was what it indicated it was doing. Additional attempts convinced me that the motion probe was not really collecting real time data at all, or if it was, not graphing what I was doing. Attempts with the force probe led to the same conclusions.

Never give up.... Shut down the computer again and try connecting the interface to the other port on the analog board, instead of the port that was in the instructions. Lo and behold, I was finally able to get the motion detector to work. The instructions had clearly stated that with a board with two slots, you were to plug into the top slot. Apparently, my bottom slot must have been the top slot in someone else's computer configuration.

My attempts with the motion probe were somewhat disappointing, in spite of the fact that I have used comparable probes before. Files were hard to find, manipulation between files awkward, and the probe insisted on recording motion data even when there was no motion. I was not able to get the force probe to work at all.

I returned to the force probe another day and spent over an hour with our Computer/Technology Specialist trying to get the probe to work. I'll spare you all the details. The conclusion is that we never could get it to function properly. We did ascertain that the probe was capable of collecting data in the form of voltages which in turn was being sent through the interface box and the analog board into the computer. In spite of that, our calibration efforts to collect real data was simply not successful.

Bridge Builder

The software Bridge Builder was my next attempt. I admit I first tried without reading from the instruction manual. My first impressions were that of crude graphics surpassed by earlier Apple II computers more than a decade ago, and help screens that seemed to be nonexistent. If all else fails, read the manual. The manual helped me make a bridge not collapse when tested by the truck that drove over it. However, the actual physics involved in looking at the stress loads on the bridge struts seemed to have been overlooked. The program could have some potential, but is not terribly exciting and misses its opportunities for sound principles of instruction. I would like to see the software called Bridge Maker mentioned by one of the teachers interviewed for this project. The ability to build a bridge on screen of different materials, then be able to build it with materials in the classroom and really test it, seems like a much better way to approach this topic. There is also a piece of software called 'Interactive Physics that could probably be used for this exercise, though it is a bit more expensive and also a bit more complicated.

SimCity

SimCity looked like an inviting piece of software, although it looked like the learning curve for mastering it might be large. The procedures specified in the PAC manual referred to completing the Tutorial on Pages 7-13 of the User's Manual. However, there was not a User's Manual to be found. Later in my investigation I did discover a help manual and tutorial that was on the CD ROM. Yielding to my own lack of knowledge about the simulation game, I called on a couple of my students who had worked with SimCity software before to try Activity 4.5, which was a scenario dealing with traffic congestion.

My students were able to find the congested traffic areas and immediately began to bulldoze several buildings and add extra roads to accommodate the traffic. Their first efforts, however, were not enough to keep the city in a survival state due to other items such as floods, fires, and tornadoes. We still don't know if the traffic patterns improved, because we were too busy putting out fires and such to get the city to last long enough to verify more successful traffic patterns. They soon tired of the structure endeavor of Activity 4.5 and wanted instead to just build their own city from scratch. That particular activity actually lasted through lunchtimes and free class time for the next couple of weeks.

My conclusion for SimCity is that it is a fun piece of software that students enjoy playing with. It may well give them a feeling for the complexity of trying to run a large city and the myriad kinds of problems both physical and financial that must be confronted. As a piece of software to address a specific instructional goal within the classroom, I feel it is too broad and too time consuming for the benefit derived. I can see how some TRAC PAC teachers have used it as a 'reward' or 'spare time' management device. Otherwise as a teaching instrument, it falls short of its goal. This is of course not to mention the difficulty with only one copy of the software on one computer.

Maglev

The Maglev Module looked like the most interesting module that could be actually used with a whole class at the same time, if the class was small. Hence, I through out the idea to my lower level physics class to see if they would be interested in pursuing it. With only eight students in this class, often with a low academic motivation, I felt that they might gain some benefit from the activities, and I would see what it was really like to teach a PAC unit. They seemed enthusiastic, so we plunged ahead.

The manual stated that one activity could be completed in one class period and that most classes could complete two. I don't know if the manual is speaking in terms of fifty or ninety minute periods, but my class took about two fifty minute periods to do the first activity, 6.1. My students were divided into optimum groups of two, were given the student handout, and the materials from the PAC to make their vehicles. It became obvious that when the actual construction time arose, the one small saw provided was not going to work for four groups of students who arrived at the construction phase at a similar time. I was fortunately able to send someone to an art classroom to borrow a few Exacto knives to aid in the process. I also found some sandpaper which worked best of all. The manual stated a materials list, but made no mention of these other items which were definitely needed.

As an instructor and observer, it was interesting to note the roles develop in the various groups. The first worksheet for rough sketches varied greatly with artistic talent and ideas, some of which were quite creative. The second worksheet to create a template was more of a challenge for some of the groups. Some in fact just started carving their car without using the constructed template. Once construction began, it seemed that one person in each group dominated the activity, while the partner mostly sat back and watched. Placing the magnets and trying to get the car to be successful on a section of the guideway proved to be another challenge. Before all the groups had cars that met the criteria, we were into our third day. We also discovered that after a move or two, the magnets would no longer stick to the Styrofoam, and hence we needed another supply - glue. Fortunately, or unfortunately, I had some glue in my prep room. I mention unfortunately because we later discovered by the cavernous holes created, that the Styrofoam was soluble to the adhesive that I had given them. After that we were able to use tape to hold them on, though it did not work ideally.

To complete activity 6.1 they were to answer the questions in the PAC handout for that activity. This part they did not enjoy, and the questions were found to be rather superficial and not really indicative of what they were learning.

Activity 6.2 had the students raise one end of a guideway until their vehicle went all the way down. They were to measure the height of the elevated end, record it, and then make modifications to the vehicle to reduce friction, etc. They than repeated the process to try and minimize the height that the guideway had to be raised. The procedure then had them calculate or measure the angle at which the guideway rested, yet it then never asked them any questions about the angles or even to do anything at all with this data. If there was a reason to calculate the angle, I missed it. The questions that followed were brief and seemed to require little thinking on behalf of the students.

Activity 6.3 had them use magnetic strips to actually propel the car down their guideway. It had them place a strip on the back of their car and then push with a second strip held in their hand. This additional strip weight caused the cars to now be unbalanced and hence they had to move the magnets on the bottom to counter. Now with their car rebalanced, they had new friction problems due to the magnet relocations. Next they were asked to put a strip on the front (why?). Now the car was unbalanced again and again they had to move magnets. Some of what had been gained in activity 6.2 was negated in Activity 6.3.

Rather than continue with Activity 6.4 and 6.5, which would involve far fewer active students due to the amount of materials, we came up with another idea for a concluding exercise. We attached our four pieces of guideway together to make one long sloped runway by elevating one end and supporting the structure throughout its length. Students than got to have three runs down the ramp, with time to make modifications and repairs between runs. We set up several timers with stop watches to record the time it took each car to complete the course. This was probably the most fun activity for the group as they got to not only compete for the fastest car, but also got to see the merits of the various designs. We also discovered that not only was it difficult to connect the guideway sections smoothly, but that some sections were actually more narrow than others, and hence one more time magnets had to be rearranged to allow the car to even pass through that section.

The total time for my class to complete the four activities was six and part of a seventh fifty minute class period. Although they seemed to enjoy the activities, as an educator I would have to question the amount of time versus the instructional goals within my curriculum that were met. If I were to do it again, I would rewrite some of the instructions, definitely rewrite the questions at the end of the activity, and supplement the activity with more info on Maglev train systems and how they work in the real world. The cars are cute, but they don't give you much of a feeling for what a train looks like. There is also little transference to the way that the electromagnets on a train actually work, or how the induction motors pull the train along the track. Induction motors are a far cry from the concept of pushing the train from the rear with another magnet.

It is also worthy of note that this series of exercises was done with the ideal lab group size of two. Without additional guidepath sections, etc. this exercise could not be done with much success at all with the typical class of twenty to twenty-five students. A lab group of six students in an exercise in futility, not education.

Recommended Changes to the PAC

In conclusion, I would offer the following suggestions if the PAC is to continue in a form similar to what I have reviewed:

1. Use instructor videos in a more constructive manner to aid the teacher in actually setting up and preparing or the process of teaching each module.

2. Use student videos to start with an intro of the merits of real world applications of the unit they are about to begin. Follow that with a student 'how to' video to get them started with the module.

3. Have educators more involved with the process of writing handout instructions, and especially the development of more suited questions to accompany the activity.

4. If materials are not included in the PAC, be sure to list the need of their procurement in advance of beginning the module.

5. Insert appropriate graphics or images in the instructor's manual and definitely in the student handouts to make them more interesting to read and easier to follow.

6. Make all computer based activities available in both Mac and Windows formats to accommodate schools and teachers using different platforms.

7. Provide a regularly updated web page giving support to the teacher. Include at this web site current links to other pages for student research, such as Maglev information sites. Also establish a support/sharing feedback mechanism for other PAC users.

8. Remove or replace PC Solve as a piece of software from the package.

9. Replace Bridge Builder with software that will allow flexibility of design that incorporates working with materials that can be used in the classroom to construct models based on the computer tested designs.

10. Consider developing modules that will incorporate CBL labs using graphing calculators which are now available in an increasing number of schools.

11. Provide more materials to adequately serve larger class sizes if the activity is to be one done by the entire class at the same time. Otherwise provide suggestions of how the materials may be used within the classroom structure as learning units to be rotated through.

DIGITIZED STUDENT DRAWINGS

When designing new modules, some students chose to draw pictures rather than only write text. Six examples of modules that these students drew are presented.

Figure D-1: Sim-Transportation

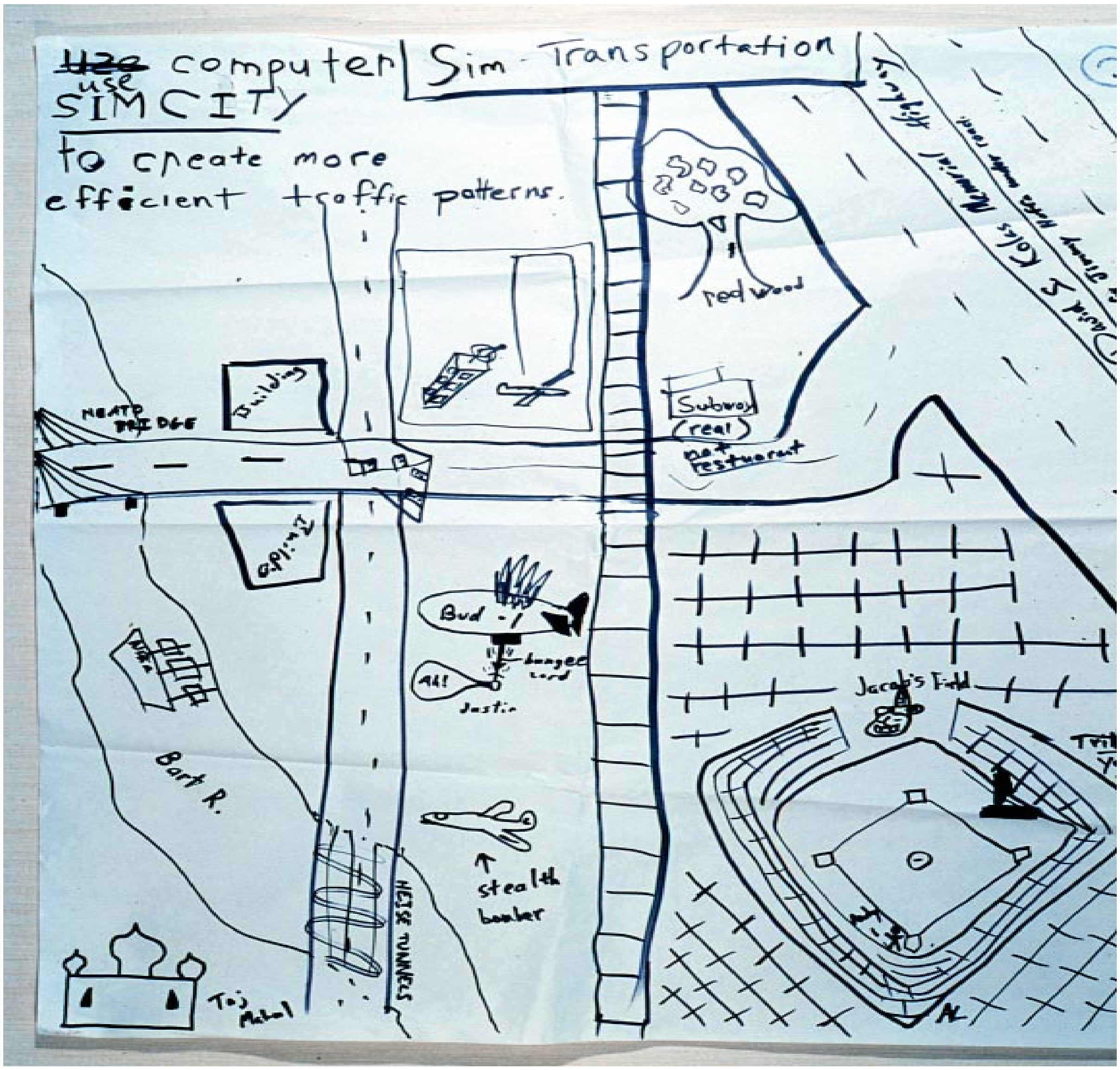

Figure D-2: Scavenger Hunt

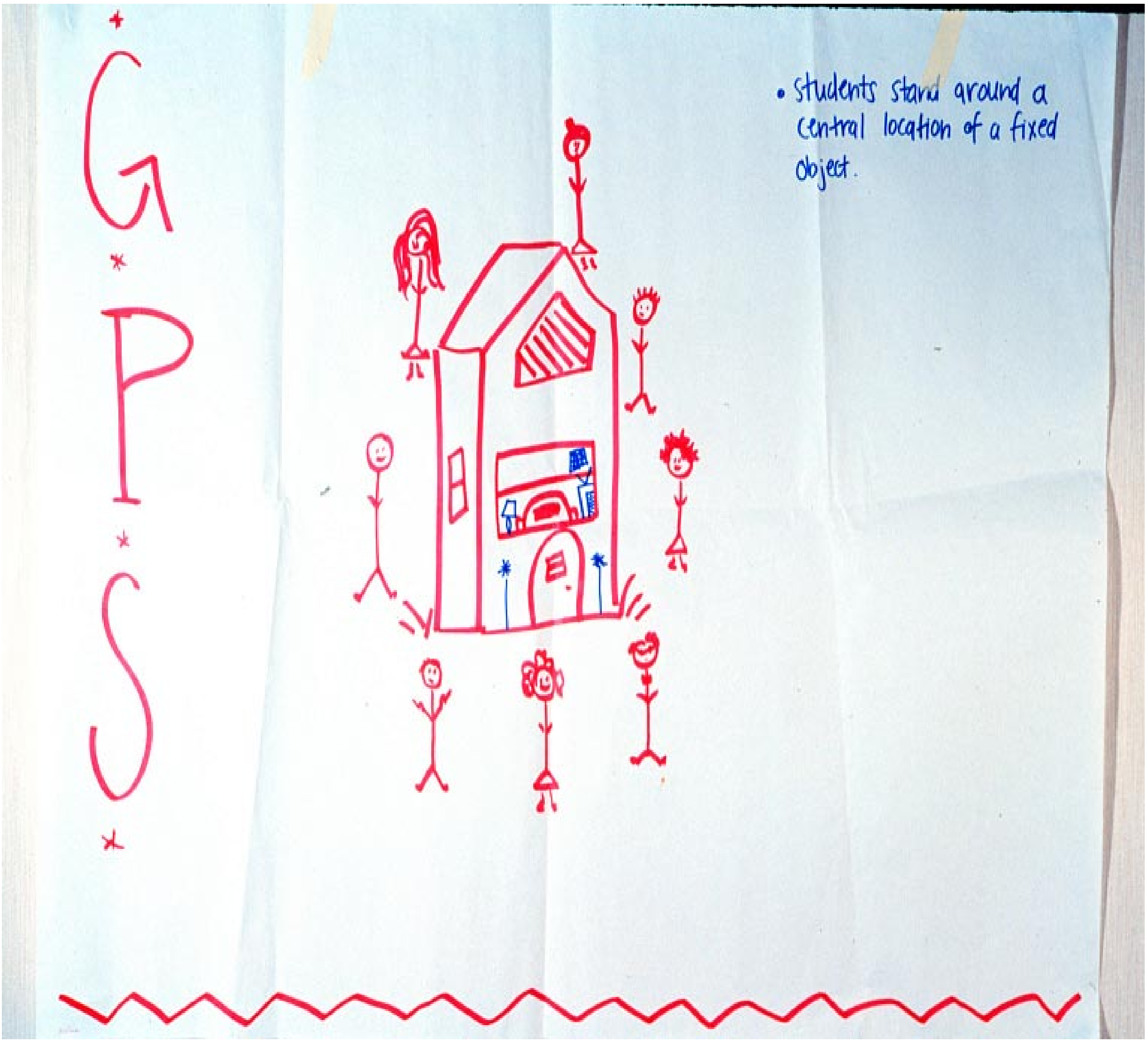

Figure D-3: Crash Statistics

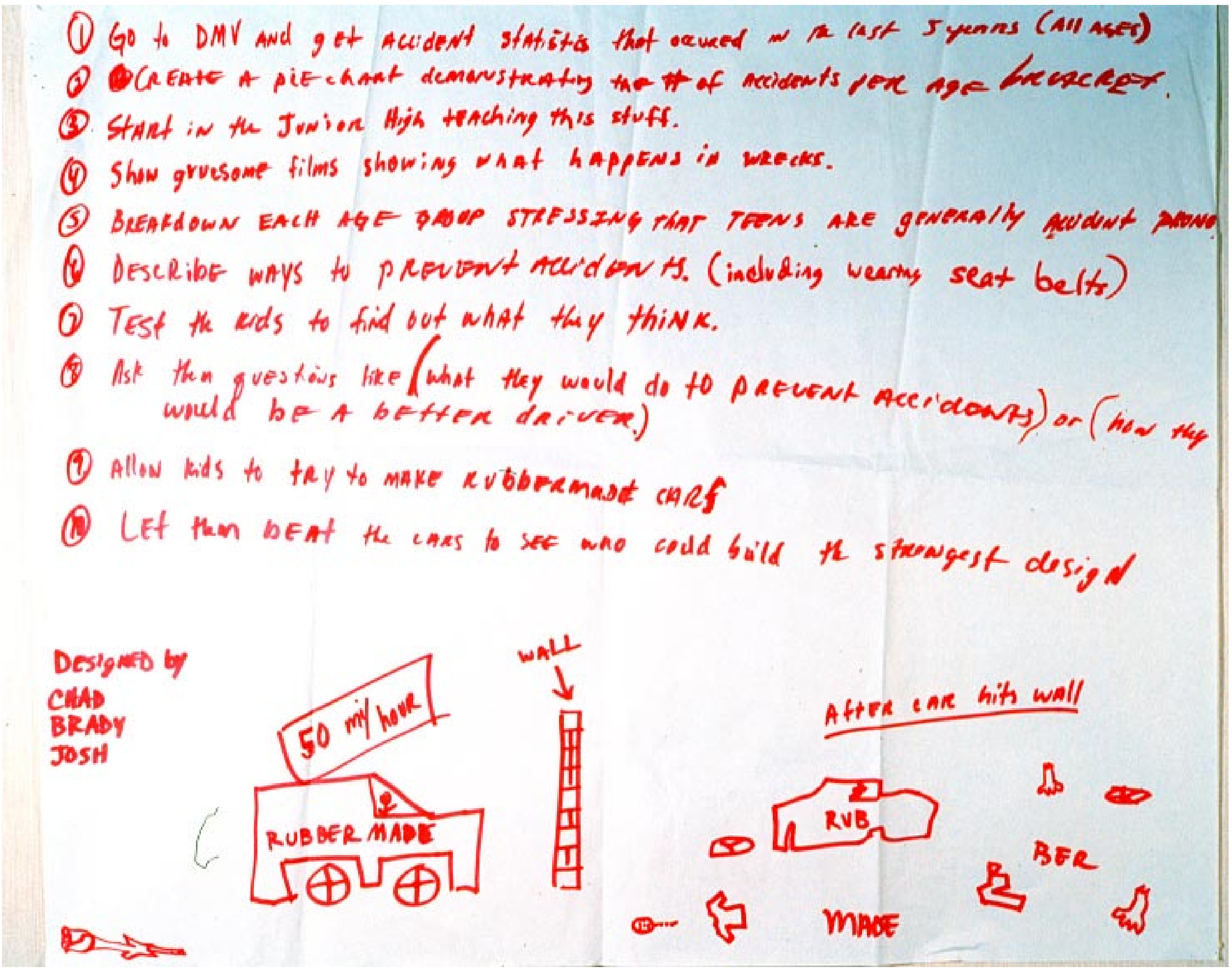

Figure D-4: Boat Design

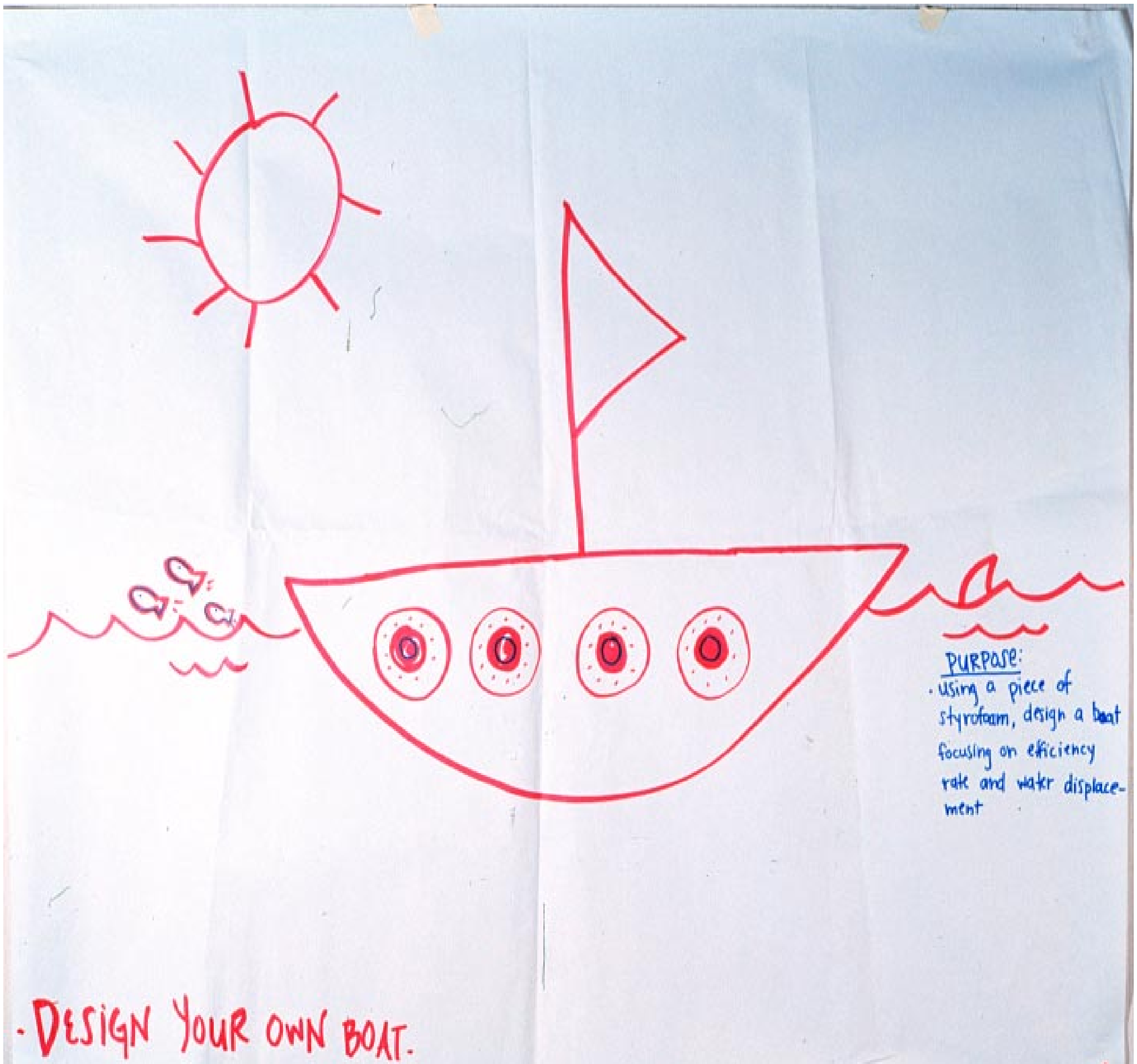

Figure D-5: Egg Crash Test

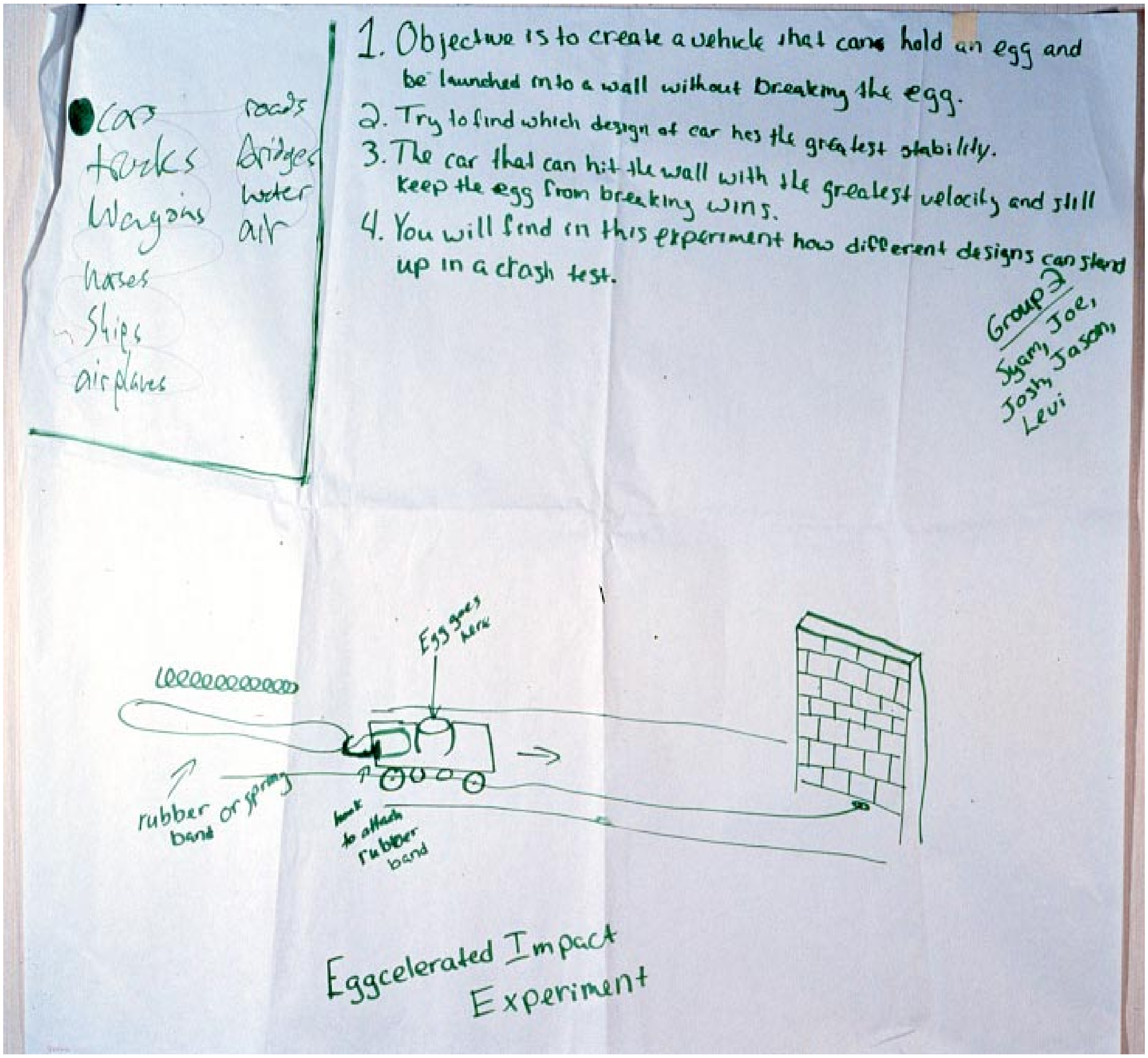

Figure D-6: Willie the Hamster