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ABSTRACT

Modular middle school technology programs, generically called Exploring Technology Education (ETE) courses, are described and analyzed to determine their strengths and weaknesses and their appropriate role in middle school curricula. Interviews were conducted with teachers, officers of the Exploring Technology Educators Association, vendors and developers of the ETE modules, and a variety of others with an interest in technology education in California. Materials were collected and analyzed, and classroom visits were conducted. The study found that ETE courses motivated students, were complex and difficult for teachers, were expensive for schools, and produced a particular set of learning outcomes that emphasized personal exploration and developing confidence rather than facilitating technical competence. Various potential outcomes are described, and findings of how well the modular format and technology-centered activities supported these different curricular goals are reported. The paper covers the following major topics: (1) the nature of ETE, including active education, activities and self-efficacy, classroom management, ETE curriculum, accommodating student differences, and social development in ETE courses; (2) content, including basic concepts, specific technical knowledge, current condition information, how-to information, historical context, social ramifications, and personal ramifications; (3) teachers, including teacher background and role; and (4) academic (cross-curricular) integration. (MES)

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Exploring Technology Education

Eric Van Duzer

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Position Paper I

September 9, 1997

Abstract:
Modular middle school technology programs generically called Exploring Technology Education (ETE) courses are described and analyzed to determine their strengths and weaknesses and their appropriate role in middle school curricula. Interviews were conducted with teachers, officers of the Exploring Technology Educators Association, vendors and developers of the ETE modules and a variety of others with an interest in technology education in California. Materials were collected and analyzed, and classroom visits conducted. The study found that ETE courses motivated students, were complex and difficult for teachers, expensive for schools and produced a particular set of learning outcomes that emphasized personal exploration and developing confidence rather than facilitating technical competence. The paper describes and analyzes various potential outcomes and reports findings of how well the modular format and technology centered activities supported these different curricular goals.

Exploring Technology Education
Eric Van Duzer
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Increasingly, technology dominates the landscape. At every level of American culture, from the mundane to the spiritual, technology is changing the way we experience life. Today, gospel is bounced off satellites and broadcast around the world, workplaces are being transformed by computerized robots, even recreational fishing has changed dramatically with the advent of fish finders and cutting edge tackle.

Technology, as a subject domain, has its own distinct architecture, consisting of its methods, logic and language. This architecture is the essence of technological literacy (as defined in this paper). Technological literacy is more than just learning to control some particular technology, to program the VCR or to write computer numerical code. Technological literacy is the ability to confront, comprehend and control the variety of emerging technologies both now and in the future. This is clearly a worthy goal for educators with potentially profound implications for today's middle school students as they prepare for life in the 21st century.

If one agrees on the need to develop this literacy through formal education, the question becomes how to best impart it. One possible answer to this question is currently sweeping nation. Exploring Technology Education (ETE), a modular, student-centered approach to technology education, "is being explored in every state, is mandated in some and is being offered in more and more school districts." (ETE Guide, 1992) In California alone, more than three hundred middle schools have introduced ETE courses.

These programs may offer unique opportunities to develop technological literacy as well as to support a variety of other worthwhile goals. Indeed, there are some goals, beyond basic literacy, which are common to all the variations in ETE (e.g., developing problem solving skills), and some which are specific to the needs of a particular community (e.g., drop-out prevention). Reporting the ways in which ETE attempts to fulfill these goals is the subject of this paper.

Methodology

In attempting to answer questions about the effectiveness of ETE in reaching its goals, I interviewed seven ETE teachers, in a wide range of California communities, from the Southern California desert to downtown Oakland. (see appendix 1) In addition to the teacher interviews, Rick B., a vice president of the Exploring Technology Educators Association, provided me with the opportunity to do a seven-day intensive ethnographic study of students in Advance Tech Middle School in an affluent community, in California.

A variety of vendor materials and curriculum materials were also gathered and analyzed. Student portfolios and other samples of their work were collected from several schools. Vendor representatives provided their perspective both in private interviews and during an CITEA convention during May, 1995.[1] The principal and core teachers (mathematics, language arts and science) at Advance Tech M.S. provided their perspective, and the current State Consultant for Technology Education, Richard Dahl, provided contacts for a variety of additional resources used in developing this paper.

The following sections will define the current state of ETE programs, develop a framework for analyzing their content and discuss issues of teacher selection and cross-curricular integration.

The Nature Of ETE

Exploring Technology classrooms typically have a common seating area surrounded by a variety of modular stations. Each station is dedicated to a specific area of technology. Often classrooms also have set aside areas for limited woodworking facilities and some mobile stations such as a Solar Energy module which can be wheeled outside. Video monitors, computers and a variety of other instructional technology tools are either included at the appropriate work stations or are distributed around the room.

The first thing that strikes a visitor to an ETE classroom is how "on-task" the students are. The second thing that happens to the visitor explains the student's behavior.

According to many of the ETE teachers, shortly after entering the room, most visitors slip into a state of fascination with all of the wondrous technology students are using; lasers, wind tunnels, computerized milling machines, robotics, desk-top publishing and so on. Perhaps the most common statement adults make while visiting is how much they wish they had "stuff like this" when they were going to school. The students seem to share this appreciation, leading to true engagement in the learning process. The enthusiasm from the students is contagious and soon most visitors are impressed with how effective the overall ETE program seems.

One of the most striking features emerging from classroom observations in schools across the social and economic spectrum is the powerful effect of the ETE format on poor and rich students alike. It transcends race and gender, making it an almost universal success in motivating students to engage and learn about technology. However, ETE is not the same in every school. Indeed, schools, their communities and the teachers themselves, shape ETE in a myriad of ways. Some programs stress career exploration, while others offer pre-engineering. In some cases, ETE

[1] California Industrial Technology Educators Association (CITEA) conference. Santa Clara, March 9,10,11, 1995

can be an expensive playground, while in others, students use the facilities such as desk-top publishing for such serious work as writing articles for local papers and magazines.

Despite these differences, the basic elements of most ETE programs are similar. The classrooms consist of roughly 16 separate modules such as "Laser Technology" or "Robotics", each housed in its own partitioned work center. Each isolated work space is self-contained, and includes all of the resources students use to explore a particular area of technology. The resources for learning about aeronautics for instance, are all contained in that module.

The modules themselves are resource-rich environments, often incorporating computers, videos, texts, and artifacts which support the student's explorations. For instance, Cal Tech's robotics module contains a curriculum binder which leads students through the material and provides "recipes" for the programming tasks. In addition to the textual material, there is a video on industrial robotics, a PC for recording answers and a set of manipulatives. The manipulatives in this module include fully functional scale models of an automated robotics arm, two conveyer belts, a computer control panel and a set of miniature barrels and boxes.

These modular classrooms are undoubtedly impressive additions to our current public schools. The variety of interesting things and activities, all made instantly available and put under the student's control, makes ETE an exciting place.

Active Education: the Basic Nature of ETE

Teachers and researchers agree that "middle school students prefer active over passive learning" (Fenwick 1987, p17), and ETE courses are very active classrooms. Indeed, the hands-on, project based nature of ETE may explain its remarkable success in engaging students. At any one time, students are watching videos, constructing wood models, operating robots, running milling machines, measuring laser beams and more. Clearly the intention is to let students experience and manipulate technology, rather than simply study about it.

In every school I visited, the program was driven by the activities. While there is a plethora of other resources and academic demands, any aspect of the course that did not directly relate to the immediate manipulative tasks was routinely skipped or, at best, superficially skimmed. At Advance Tech Middle School for example, students in the bridge design and building module abandoned the text as soon as they could discern how to create their bridges without it. They completely ignored the module's video resources except when they showed the model bridges being constructed and tested. Indeed, these students exemplified the concern Alice K. expressed when I visited her classroom. She said "students get caught up in the doing part and miss the thinking part". This same behavior can be observed in ETE programs everywhere.

Despite Alice K.'s concerns (echoed by other teachers and vendors), there is some evidence that experiential learning is both motivating and effective in transmitting certain types of information. Clearly, the activities in ETE motivate students far more effectively than the text or video aspects of the modules.

Activities and self-efficacy:

Many of us have *seen* lasers, *read* about industrial robotics or *watched* a building being constructed. Each of these experiences generates some level of interest. However, to generate the level of enthusiasm observable in ETE classrooms, the curriculum needs to actively engage the students. Much of ETE's power to generate this engagement seems to stem from the fact that the students themselves get to control, operate and explore the technology on a first-hand basis. This shifts the locus of control to the students, both empowering them by increasing both their personal responsibility and authority over their education, and reinforcing their sense of self-worth.

The reasons for the effectiveness of this hands-on approach go beyond the basic issues of student development and the argument that active learning is particularly suited to this age group. Indeed, attribution theory (Ames, 1992) sheds considerable light on the motivating effects of these activities. Not only do students gain a sense of increased importance and control, the physical manifestations of their efforts provide powerful evidence of their self-efficacy. When the robotics arm reaches down, picks up the barrel and drops it onto the conveyer belt, or the milling machine races through its program cutting out a game board, students have unambiguous proof that "they did it!". This often results in students shoving their fists into the air in the almost universal sign of success and accomplishment.

Classroom management:

The active nature of ETE middle school courses present some challenges similar to those in traditional industrial arts (IA) programs. Thirty students, in the midst of a "squirrelly" developmental stage exemplified by difficulty in maintaining attention or focus, are engaged in sixteen different activities using thousands of dollars in high-tech equipment. To make matters more complicated, most of the module's manipulatives contain multiple parts and pieces. There are clearly opportunities to be destructive, or simply to abscond with a particularly fascinating piece of equipment. The removal of just one piece can have a dramatic effect on the use of that module. At a school in Silicon Valley, one of the modules had been out of commission for two months because someone had slipped away with two little fasteners. Unfortunately, many of the manipulatives are custom made and cannot be repaired with off-the-shelf parts.

Teachers deal with these issues in different ways. In Oakland one teacher stands by the door as students leave, asking each student to deposit a scrap of paper picked up from the floor into a wastebasket she is holding. She indicated that it provided both a disincentive for theft (students had to show their hands and talk to the teacher) and a way to accommodate the lack of janitorial services her classroom had to endure.

Good classroom management is particularly important in ETE classrooms. The level and variety of activities can be a challenge to any teacher's classroom management style. Even the modular furniture can create difficulties in terms of maintaining a controlled environment. The furniture in an ETE classroom has wide "fins", extending past the ends of the work tables, effectively blocking the students from interacting with others while at their work station. They also prevent the teacher from directly observing student behaviors most of the time. In some schools this has resulted in: students poking pencils through laptop computer screens, breaking equipment by using it in inappropriate ways, and ignoring the canned curriculum in order to play around.

However, while ETE has some structural disadvantages common to many activity-based courses, the effectiveness of the programs suggests that it must also have advantages. Perhaps the most important advantage ETE has in supporting classroom management is the inherent appeal of controlling the technology in an active environment. Just as the project in a woodworking class is a powerful motivator which can be offered or withheld to shape behavior, so can the module activities. Many teachers use the threat of shutting down access to the modules to force compliance with classroom rules. For instance, Barry B., a teacher in Silicon Valley, uses the modules as a reward for beginning sixth grade students who complete their class-wide projects early. However, any misbehavior results in the immediate suspension of those privileges. He and many others indicate that this is a very effective technique.

ETE Curriculum:

The curriculum itself is also designed to engage students in productive, on-task behaviors. While they work relatively independently, following the curriculum at their own pace, very little is left to the discretion of the students. The prescriptive nature of the ETE "canned" curriculum helps the teacher maintain a smoothly running program. Students are "led by the hand" through the material. Every step is carefully laid out, leaving little opportunity to personalize the tasks or the approach to the subject. These are clearly not resource-rich environments where students are "tossed in" and told to learn what they can or want to. The canned curriculum shapes the program to a substantial degree.

At its best, the curriculum is designed to provide guided discovery opportunities. For instance, Paxton-Patterson's aeronautics module asks students to position blocks of different shapes in a wind tunnel and observe how the air moves around them. This allows students to "discover" principles of aerodynamics which are later related to textual information on "drag" and "lift".

In general, however, the discovery nature of ETE curriculum is currently quite limited. Most of the curriculum is presented in a strict step-by-step format such as the Paxton-Patterson Robotics module which spoon feeds technical directions for programming and provides line-by-line instructions for wiring an automated manufacturing cell. Rather than asking students to employ a variety of resources in developing their own solutions to problems presented in the curriculum, most modules have predetermined "right" solutions that require the students to follow a prescribed path in order to ensure success.

Both in terms of the classroom management discussed earlier, and in terms of building self-efficacy, a step-by-step approach makes sense. The instructions become enabling tools designed to ensure success. Despite the obvious limits on cognitive challenges it imposes, ETE modules are written to provide "positive learning experiences for all students". In almost every case, the goal is guaranteed success. This requires carefully articulated tasks and sets of clear and concise instructions. If students are faithful to the text, they will eventually succeed in the activity that is driving their motivation to learn. This results in a stronger sense of self-efficacy and a greater tendency to engage new information with greater task persistence (Ames, 1992; Skinner, 1990).

However, the disadvantages of such narrowly defined tasks and methods are several fold. First, all students are directed down the same path and this limits the curriculum's ability to accommodate learner differences. Also, with such carefully defined approaches, little independent thinking occurs beyond deciphering instructions and the guess and test approach to problem solving. The limited nature of independent problem solving is a particular problem for ETE, in that many teachers and vendors routinely articulate one of their major goals as teaching students to become independent learners.

It also has implications for the level of cognitive development ETE supports. When the main task of the student is to blindly follow a set of instructions, little "meaning making", analysis, synthesis or evaluation is required in short, no higher-level thinking (Bloom's taxonomy). Indeed, to the extent that some instructions merely say "put this here and that there", students may not even need to comprehend the content which the activity is supposed to illustrate. To the extent that the curricular demands shape student cognitive growth, explicit, step-by-step instructions may do little more than teach students how to follow directions.

Accommodating student differences in pacing the course

Both the level of content mastery required and the process of mastering it are designed to allow almost universal success. However, this creates another problem. If the slowest student can succeed in the module during the standard time frame, more advanced students will do so in less than the allotted time. In order to accommodate this range, most curriculum efforts include enrichment exercises.

The enrichment exercises go beyond the minutely described tasks, central to the module's basic curriculum. It is in these exercises that students begin to work more independently, generating their own process and using the resources in uniquely personal ways. For instance, the Cal-Tech robotics module at Advance Tech Middle School has an enrichment exercise that requires students to synthesize the information presented in the basic curriculum in order to develop a fully automated work cell. This involves some real problem solving and the ability to develop a more global understanding of computer code applications and their interface with the components of the system. In this way, ETE programs are clearly presenting a differentiated curriculum that is based on the ability and motivation of the students.

While every student will encounter the same number and variety of technological areas, they will not all have the opportunity to go beyond the basics. This means that advanced students will gain skills in active problem solving that are not available to slower students. Therefore, it is important to recognize the tension between the self-paced modules and the inflexible structure of the ETE rotations.

Social development in ETE courses:

According to the Caught in The Middle report (Fenwick, 1987), from the state of California, middle school is a time of evolving socialization with uniquely dramatic effects on the students. Basic ETE programs support social development in a carefully prescribed fashion. For instance, the furniture is designed to isolate pairs of students, allowing them to suffer set-backs in semi-private. This limits social embarrassment and its inhibiting effects as students try and fail in the process of stretching their capabilities and knowledge. The furniture also helps the teacher limit unwanted cross-modular socialization that could result in greater distractions and less focused activity. While not every school can afford specifically designed furniture, the separation of teams and tasks that these segmented workstations provide is a central feature of many ETE classrooms

The negative effects of competition are also greatly reduced in ETE. With every pair of students working on something different, and the basic "mastery" approach to the modules, the threat of social ranking and therefore blows to the student's self-esteem are limited. However, while these are important attributes in terms of the social environment, the most salient aspect of the ETE programs in terms of controlled socialization is embedded in the act of pairing students.

Virtually all of the commercially available curriculum is designed for pairs of students. This use of cooperative learning offers distinct advantages such as increased learning through peer interactions and a reduction in negative effects of feelings of personal inadequacy in times of failure (Chambers and Abrami, 1991). It also represents an important element during the most "complex social development period in the life of a child".

For a number of both social and economic reasons, teaching students to work together is an important goal. In a gang-riddled neighborhood in Oakland, the ETE teacher argues "that teaching students to get along and work together is one of the most important outcomes of ETE". She, and teachers such as Rick B. (from an affluent community), regularly shift partners at the end of each module rotation. This practice teaches students to deal effectively with different types of people. This not only supports the immediate goals of ETE, but also supports the more general business and developmental goals articulated in the SCANS (1991) and the Caught in the Middle (Fenwick, 1987) reports such as working collaboratively towards common goals. However, rotating partners is only one system of pairing students.

In Modesto, Bob R. must accommodate a large population of immigrant Hispanic students. Therefore, he administers a basic reading level test and then pairs poor readers with those who have more advanced skills. In this way the pairs of students can work together in order to effectively deal with the written materials. In Silicon Valley it is handled very differently. There, students can select their own partners, and therefore, friends have the additional motivation of working together. Still other schools use cross-ability grouping for a variety of reasons.

> The effects on the student of working with a partner, even one selected randomly, came into sharp focus during a set of detailed observations at Advance Tech Middle School. Shortly after the class rotated to new modules, one partner in the construction module became ill and was absent for a couple of days. At this point in the process, the remaining student was attempting to build a scale model of a small shed's framed walls and roof. Despite a paper pattern, written instructions, and a physical model to compare his work to, this student became increasingly frustrated, self-destructive, and impatient. Many of the stumbling blocks he encountered would have been (and

were later) quickly resolved if his partner had been there to talk things over with. This was not a case of mixed ability grouping, where the missing partner was more advanced. It simply reflected the insecurity of working in isolation in an uncertain environment that stretches one's perceived competencies. The lack of a partner not only affected the student, but also the teacher.

As the student, working alone in the construction module, became frustrated he increasingly turned to the teacher for help. Soon even momentary barriers became impossible tasks. The result was less persistence and effectiveness and an apparent lowering of the student's self-esteem, evidenced by increasingly common comments such as "I can't do this", and "This sucks!". Once the partner returned, most of the negative behaviors subsided and the students once again worked together to independently negotiate the rest of the module's tasks.

In addition to the positive effects on student's independent efforts, and the freedom it provides to teachers, pairing students provides all the benefits of peer tutoring, thus increasing the learning of both the slower and more advanced students (King-Sears et al., 1995). It also seems to constrain destructive behavior to some extent and to provide the personal support students need at this age.

Despite the effectiveness of pairing students, most of the modules do not fully incorporate the fundamentals of cooperative learning. Of particular concern is the fact that the fates of the two students are rarely linked together. In many modules the cooperative structure breaks down into "parallel play". By not making both partners responsible for the team's success the effectiveness of this approach in encouraging peer tutoring and the inclusion of slower students in the modules activities are diminished. Often vendors and teachers will argue that the sheer quantity of material and tasks demanded of the students require that both contribute. However, observations established that while this may be true, much of the content is skipped, and whereas an activity may demand two sets of hands, it rarely requires two active minds.

The nature of ETE can be summed up as a highly prescriptive, self-paced, resource-rich program of limited exploration or discovery, but offering widely ranging experiences. These experiences, along with the content which supports them, are routinely employed in the service of a variety of goals. Chief among these are developing a general technological literacy (i.e. the ability to confront, comprehend, and control technological artifacts), exploring a variety of career domains, becoming increasingly independent learners and developing effective problem solving skills. In order to achieve these goals, curriculum developers mix and match a range of content and resources that is intended to lead students to a deeper understanding of technology as a separate domain with its own logic, artifacts, past and future. The following section analyzes the subject content and provides a framework for evaluating the types of content and their relative value in an ETE course.

Content

Exploring Technology Education is a study of technology as a distinct subject domain, rather than as applied science or an extension of vocational education. Technology is the engineered interface between science and society and therefore embodies parts of various classic disciplines. Yet it has its unique history, social relevance, methods of discovery and systems of operation which are different from the classic subjects. Therefore, in order to develop a comprehensive view of technology as a distinct subject, many elements must be brought together with a unique focus. If the underlying logic can be defined and taught, students will be more effective citizens in an increasingly technological world. To that end, the following section disentangles the content elements currently employed and examines how they fit and shape ETE programs.

In an analysis of the content of ETE and how it is shaped by factors such as the teacher's preferences, commercial formats and the community, it is necessary to begin by breaking down "content" into its different types. I have developed the following categories offered through the ETE modules I studied: basic concepts, specific technical knowledge, current condition, how-to, historical context, social ramifications, and personal/career implications. To varying degrees all of these are included in ETE courses. However, due to time constraints, priorities must be set which sacrifice some types of content in order to emphasize others. The priorities of a specific school's ETE program can therefore be analyzed by the relative relationships between the following types of content.

Types of content

Basic Concepts

"Basic Concepts" are the underlying fundamentals which provide the logical structure of a specific technological domain. Understanding that electricity requires an uninterrupted circuit, that when a small gear engages a larger gear, the small gear turns faster, or that two dimensional drawings can accurately depict three dimensional objects, are the types of basic concepts embedded in the curricula of various modules. Often these basic concepts are presented in the module's activities. Bob R.'s "Little House" module is an excellent example of how this is done.

As part of his construction unit, Bob R. has students design a model house using a set of computer templates. The final design includes a floor plan (complete with furniture and appliances), elevations, and a landscaped backyard. Once the computer design is completed, students print out the picture of their house. The plot and building are then cut out and folded into their appropriate shapes. This allows students to experience the way two-dimensional drawings translate into three-dimensional space. It is a concrete method of teaching a concept which underlies every aspect of the construction industry from architectural design to carpentry.

Basic concepts are also commonly presented in the text and through other resources. The Tech 2000 electronics manual impresses students with the need for completed circuits. However, that information seems to take on personal meaning only as the students are trying to determine why the circuit they just built won't ring the buzzer or turn on the light.

Not all modules emphasize basic concepts. For instance, a common approach to construction modules asks students to build a model. The students cut and glue thin strips of wood to create a miniature stud-wall or shed. At Advance Tech Middle School, students measure the pieces against a paper pattern. They also have a completed model they can refer to in constructing their own. The only basic concept that seems to be offered here is that building frames consist of lots of little pieces, and that those pieces are of different dimensions. However, no portion of the module curriculum relates the types and sizes of specific pieces to the job they perform. Students do not engage the concept of load distribution or need to comprehend the basic issues which dictate why a stud wall is built the way it is. Therefore, even if students learn the sizes and names of the framing (they currently do not), they are not really learning a basic concept which will provide widely generalizable knowledge. Indeed, the names and sizes of the wall's framing members are not basic concepts, but are the "stuff" which the next category is made of.

Specific Technical Knowledge

"Specific technical knowledge" is distinguished from basic concepts by its level of specificity. For instance, while one basic concept in power transmission is that a larger gear will have a lower rate of rotation than a smaller gear with which it is engaged, specific technical knowledge would include greater detail. For instance, it might continue deeper into the subject by informing the student that a 3:1 ratio involves two gears where the larger one has three times as many teeth of the same "pitch" as the smaller gear.

The basic concept is more general, yet in the case of gears, it would be insufficient to allow students to use their knowledge in an effective way. It is useful to think of specific technical knowledge as an enabling type of content which goes beyond exploration and gets into knowledge and skill development.

There are some structural limitations to the level of specific technical knowledge these programs can instill. First and foremost the modular nature of ETE presents the various technologies in isolation. Unlike traditional courses, or programmed instruction with its sequential "frames", ETE modules are stand-alone units which neither build on one another, nor reintroduce earlier content in new and different ways. All a student will learn about aeronautics, robotics, desk-top publishing etc., is what will fit in five to ten class hours. Once the module is completed, students never again apply or integrate the module's information during the course. Given this situation, the ETE format is poorly suited to generating a body of specific technical knowledge.

Current Condition

Current condition information seeks to define the current state of the technology. For instance, the Cal-Tech robotics manual uses a series of rhetorical questions and illustrated answers to teach students that computers take a variety of forms, from simple chips in automobiles, to a room full of tape drives and massive CPU's. The purpose of current condition content is to help students develop a broad awareness of the types of artifacts, experiences, language, and activities currently inherent in a particular domain.

A combination of resources and approaches contribute to the delivery of current condition information. Videos, included in virtually every commercial module, regularly provide a glimpse of the modern state of the art in society and industry. These videos (and laser disks) often interweave the images of current technology with issues involving its social/personal relevance. The text also contributes to descriptions of the current state of the art. Even the hands-on activities are designed to provide first hand experiences of what current technology looks like, feels like and acts like.

Some states have put a special emphasis on providing cutting edge technology to expose students to the current state of the art. For instance, in Georgia, many of the schools abandoned the scale manipulatives common to ETE modules and replaced them with industrial-quality equipment. Their intention was to give students more realistic experiences and begin the process of industrial training leading to increasingly vocational studies in high school and beyond. This approach clearly puts greater emphasis on the current state of the art than the common range of model manipulatives. However, it begs the question, "How important is having a clear picture of today's technology and its current applications when much of it will be obsolete before these middle school students graduate from high school?"

Historical context is much more important in terms of understanding and coping with the rapid changes technology will bring than mastering today's technology. Basic concepts will still underlie future technology in most domains. Indeed, a variety of other aspects in the curriculum may have a longer lasting value for the students than current condition knowledge. However, current condition information may provide some relevance for the student's efforts. Indeed, when students accept the relevance of what they are studying and how it affects their lives now, they are likely to become more engaged and therefore gain more knowledge. Almost all currently available modules devote a sizable portion of their space and time to this type of information.

How-To

How-to information is usually presented in a practical fashion which enables students to control the technology they are exploring. Computer literacy modules are full of literal how-to types of content: "Highlight the paragraph, click on the EDIT menu, select CUT ...". In many ways the highly structured how-to instructions have a positive influence by improving the success rate among students at an age when failure can have an exaggerated effect on future educational efforts (Ames, 1992). However, providing complete step-by-step instructions subverts the motivation for acquiring specific technical knowledge. It also does little to stimulate cognitive growth. Therefore, the balance in how-to instructional content is between the guarantee of success and the level of cognitive challenge required to succeed.

To some extent the community, through its children, its aspirations and its involvement in education shape the level of challenge possible in the class. An example of an ETE program tailored to the needs of its community follows.

> In Oakland, Alice K. uses a Tech 2000 lab to build self-confidence and reinforce the attitude that, with effort, every student can succeed. To accomplish this, she sacrifices intellectual rigor. Students can succeed by just copying the text's illustrations with models such as LEGO Machines. They can therefore successfully complete the exercises even if they never engage the module's written or video resources.
>
> Written assignments are graded on the basis of how many lines a student wrote. There are few demands and little thoughtful problem solving. Clearly, Alice K. has shaped the tasks and the how-to information to maximize success and minimize challenge. In these ways she has tried to satisfy the needs of her student population. This is one class in a district with a drop-out rate of 40%, which encourages kids to stay in school. However, it is unclear how effective an unchallenging environment is in building a student's sense of self-efficacy or in developing real competencies.

However, not every effort to develop how-to knowledge involves such explicitly directed exercises. "How-to" information is also often learned as part of the discovery process involved in the module activities. For instance, an exercise might require students to wire a parallel circuit using the textual information presented earlier, or to independently construct lines of computer code to position a milling machine. However, as a general rule, the modules reserve these types of challenges for "enrichment" exercises not included as a basic part of the module. Indeed, virtually every module examined was almost entirely carefully scripted to ensure success.

The actual instructions for manipulating the variety of technological artifacts, are presented in a variety of forms. The most common is in the form of written instructions arranged sequentially, day by day, in a binder. However, not all vendors rely on written instructions. Synergistics presents their instructions on video, and the Tech 2000 labs include interactive computer instruction.

Historical Context

Historical context provides an overview of the evolution of a particular technology. This serves a variety of goals. For instance, the evolution of flight alerts students to the future potential of aviation. The history of bridge building presents the range of successful designs and informs student thinking in terms of the salient design issues. Given that virtually all emerging technologies are a combination of past technologies, this type of knowledge can play an important role in a student's understanding of that domain.

The difficulty in presenting this type of background information, in a self-directed learning environment, is that it lacks immediate relevance to the classroom activities and therefore seems to be mostly ignored. Whether the information was presented through video or textually, the students I observed simply brushed over it without truly engaging the content, giving it personal meaning or integrating it into other aspects of the module's learning activities.

Some method must be employed to actively engage students in this contextual information or they will simply miss it. Whether efforts are patterned after interactive computer programs such as "Where in the world is Carmen Sandiego" or are somehow integrated into the module's activities, (i.e., design bridges from the 16th, 18th and 20th centuries) it seems likely that students will gain little from a mosaic of background information presented tangentially to the central tasks of the module.

Social Ramifications

The social and personal ramifications of technology are large enough to support a separate course, and do in the form of courses titled Science, Technology and Society. These are classes whose primary focus is on teaching students to recognize the social implications of technological decisions through issue based pedagogy.

It is undeniable that society is shaped by technology. The effects of automobiles, telephones, printing presses, computers and an endless list of other "essential" technologies support this point. Also, there are clearly personal effects, such as career options, shape of the living environment and the resolution of ethical decisions forced by emerging technology, which have a legitimate role in ETE. All of this is part of a full awareness and comprehension of technology as a distinct subject domain.

In the modules examined, there was little analysis of the general effects of emerging technology on society. There was nothing which could be considered controversial. Students routinely learn how technology is shaping the work place but displaced workers, corporate restructuring or issues of economic shifts are basically ignored. No curriculum materials discussed the effects of automobiles on society or the emergence of building trends which reduce housing availability to those in the lower middle class, etc. However, this was not the case in terms of careers.

Personal Ramifications

The personal career relevance of these modules is something that many teachers and vendors stress. Clearly, ETE offers unique opportunities for students to experience some aspect of emerging technologies related to modern industry. Where else either in school or in their daily lives will students experience programming robots, producing audio and video tapes, using a wind tunnel or measuring the defraction angles of laser beams? To some extent this exposure presents an excellent survey during which students may discover aptitudes and interests that lead them into a career area.

Careers are formally introduced in a variety of formats. For instance, the Paxton-Patterson system includes careers by requiring students to put magazine and newspaper want ads in their portfolios. Synergistics and others show industry-in-action in their instructional videos. Teachers such as Alice K. hold class-wide units on careers. However, the career relevance is often superficial except in the sense of performing some related task. Even with her separate unit, Ms. Kruze believes careers are the "weakest part of the curriculum". Much in the way industrial arts texts include a short chapter on careers, these modules offer quick glimpses without integrating careers in any true sense.

However, not every district is even interested in stressing the career aspects of ETE. In one school located in an affluent community, parents expect their children to enter private universities and therefore resent any efforts to interest them in technician-level occupations. Rick B., the ETE teacher there, purposely down plays the career aspects in defining his program. Where careers are incorporated, they tend to be focused at the higher levels such as engineer and architect rather than electronics technician and carpenter. Clearly this is one aspect of the curriculum content that differs significantly from one school to another rather from one module to another.

These various types of content have obviously fuzzy demarcations and clearly overlap to some degree. However, to the extent that each type represents a different set of goals it is of some value to distinguish among them. Given the time constraints, the curriculum can usually only emphasize one aspect at the expense of others. For instance, the way the Paxton-Patterson Aeronautics module is designed, historical and current condition information consumes the majority of the module's first three days. Later, it presents a variety of specific technical information such as the Bernoulli principle, while the hands-on exercises are geared toward imparting basic concepts including lift and drag.

In contrast, the Cal-Tech robotics module minimizes background information, focusing initially on the current condition of industrial robotics and computer controls. Later the curriculum becomes almost entirely explicit, how-to instructions which enable students to control a robotics arm and a pair of conveyer belts.

Given the variety of possible combinations of types of content and areas of emphasis, the selection of modules clearly involves more than a question of subject areas. It also represents either a deliberate or accidental blend and balance of the various types of content.

Some types of content are better suited to the structure of ETE than others. "How to" information is obviously central to a program which is motivated by hands-on activities. Specific technical information is limited by the short time frames and lack of cross-modular content building. In some ways, carefully directed hands-on activities are better suited to basic concept delivery and an awareness of "what is" than they are to either specific content or developing how-to knowledge.

Historical knowledge is the least affected by the rapid rate of technological change. Clearly history evolves as each second passes. However, once learned, literal history never becomes obsolete (although it becomes subject to reinterpretation) and therefore this type of information holds its value the longest, with the possible exception of process knowledge.

Process knowledge may be the most valuable of all. Yet, it is only an aspect of content in the broadest sense. The skills associated with working thorough the modules are fairly generic. The tools of discovery, such as identifying problems and following instructions, the methods of comprehension, such as learning vocabulary and synthesizing material from different sources, and the basic techniques of tracking down information, such as using indexes and tables of contents, can all be applied regardless of the specific technology (either present or future).

Clearly, the tools of discovery are not stagnant. Indeed, with the emergence of the World Wide Web and other computer resources, the process of discovery is quickly evolving. However, the process methods are clearly more generalizable than how-to, specific content, historical context or basic concepts. Therefore, since the purpose of ETE is to empower students to thrive in a rapidly changing technological society, these skills are important aspects of the programs.

Some teachers believe that process is the most essential aspect of these programs, that how-to information, while empowering students in their immediate tasks, is too limited to be considered useful skill training, that the short time frames are specifically designed to support the exploratory nature of the course, and that specific technical information should be limited in favor of giving students a sampling of activities to stimulate their interests in a variety of areas. Students will not learn electronics in five days regardless of how bright they are. But, in a semester, they may learn how to make sense of new technologies using a combination of tools and experimentation.

The Teachers

Among the most powerful influences shaping the content of an ETE course are the teachers themselves. They shape the program, both through their selection of modules, and the role they play in the classroom.

The question of who should teach an ETE course is an interesting and complicated one. The teacher's background, stage in his or her career, and willingness to move from a knowledge dispenser to a facilitator all affect the form ETE courses eventually take. Yet, in a number of states including California, there are no statewide guidelines or requirements. Indeed, in California, districts are free to hire any teacher they deem fit. There are examples of English, mathematics, history and art teachers currently running these courses.

Some vendors argue that any proficient teacher willing to undertake the challenge of an ETE course can be successful. They discount the importance of a teacher's subject background, arguing that in their new role as a facilitator their subject specific knowledge is no longer the critical issue. While this may be true to some extent, it is also true that the types of demands in an ETE classroom suggest that certain professional backgrounds will better prepare teachers for these courses than others.

It is a mistake to discount the technological content of ETE or the scientific basis of that content. Sixteen subject areas based on science, realized through technology, are being presented in a classroom teeming with instructional technology such as computers, laser discs, and videotapes. This instructional technology is supplemented with an assortment of high tech manipulatives (lasers, robots, milling machines). The technological environment leads to a common opinion among many of today's ETE teachers that a science or technology background is an important asset. This opinion seems well founded and is reflected in the current teaching staff in these programs.

The most common background for ETE teachers is industrial arts (IA). This is a natural outcome, since, to a large extent, ETE has supplanted traditional IA courses, and because "technology education" has long been a part of the IA domain. However, science teachers are also increasingly being called upon, and now they represent a substantial minority. In fact, current trends indicate that science teachers may eventually be the majority.

The difference between hiring a science teacher or an industrial arts teacher is more than academic. Different disciplines approach problem solving and assess student efforts in different ways. A particularly significant difference is in their relative emphasis of product v. process. Through the selection of modules and the choice of tasks, this distinction can have a profound effect on the shape of these courses.

The very nature of science vs. technology suggests that teachers with these different backgrounds will approach the process/product question differently. These differences are founded in the methods, goals, and traditions of the two subjects. Bob R., and others, have argued that the scientific method is fundamentally designed to add to a body of knowledge, while the technological method is designed to create useful artifacts and processes. If this is accurate, it supports the supposition that IA teachers are more likely to be product oriented than science teachers.

This supposition is also supported by evidence in the field. Rick B. and Bob R., both experienced and highly regarded ETE teachers, agree that most former IA teachers are very product- oriented. "They appreciate the power of a take home product as a 'carrot' to motivate student learning." Rick B. maintains that current modules have been shaped by this attitude to be more product oriented than they were originally designed for.

On the other hand, Alice K., a former science teacher, was clearly more interested in the process than the product. She was quite adamant that the focus of her program was to "Teach process... these are the skills which transfer from one lab activity to the next". Her course involves hands-on manipulatives, such as assembling LEGO type components, but few or no projects in which students take home a finished product.

These differences in approach illustrate how various types of modules, assessments, and tasks are affected by the teacher's background. Indeed, it is clear that a teacher's prior experience affects the methods, classroom management techniques, and the professional expectations which ultimately shape these programs.

However, the effects of the teacher's background are only one example of how teachers impact these courses. Indeed, despite its importance, background probably plays a secondary role to the willingness of the teacher to move from a knowledge dispenser to a facilitator. Both current teachers and a variety of commercial vendors have indicated that the teacher's willingness to adopt this new role is the critical issue which in large part determines the success or failure of an ETE program.

Despite the value of a scientific or technology background, it is unlikely to find a teacher with extensive knowledge in aeronautics, robotics, hydraulics, desk-top publishing, construction and so on for sixteen different areas. Indeed, teachers who try to master all the subject areas in an ETE lab just "drive themselves crazy". Instead of mastering the content, teachers as facilitators are required to master the process. This is different than the facilitation roles adopted in other disciplines. It is more than simply shifting the burden of teaching and learning to the students. In other situations, the teacher still maintains the subject specialist position, shaping the facilitator role in ways which reflect their content mastery. In ETE, teachers leave content mastery behind. They are required to adopt a "mutual discovery" approach in which they explore the content along with, rather than ahead of, the students.

While experience improves the teacher's over all mastery of content, the breadth of these courses suggest that trying to remain a subject specialist is not the most effective role to adopt. Yet, having become accustomed to being the "sage on the stage", they find that being a process facilitator is less rewarding and therefore less desirable. This manifests itself in a variety of ways.

In A.B.C. Middle School the ETE teacher has eliminated the use of written directions in each module and restored himself to center stage by trying to guide all sixteen pairs of students with verbal instructions alone. In Modesto the ETE teacher jettisoned the individual modules all together, and regained center stage by developing his own curriculum in which he guides class projects in an environment where virtually no other learning resources are available besides the teacher and a project manual.

These are extreme examples, but they represent a common feeling among participants at the 1995 California Industrial Technology Educators Association (CITEA) conference where many members expressed their discomfort with the facilitator role. This reticence lingers even after they become more comfortable with both the process and the content. Indeed, a system designed to get students to learn on their own, offers different rewards and fulfills different psychic needs than traditional teaching and therefore, remains a significant challenge to administrators trying to staff these programs.

Academic Integration

The Exploring Technology Education: Curriculum changes and Design Solutions (1992), a document created as an initial framework for California's ETE programs, emphasizes the integration of core academic content. This reflects the national trend towards greater technical/ academic integration and the recognition that "The continual change in (technology) requires students to possess a strong foundation in the academic core...". (ETE Guide 1992, pvii)

The inclusion of more academic content clearly serves the interests of both the core and technology courses. Including topics from math or skills from English in the ETE activities, provides a valuable sense of relevance to core content, which often seems abstract and removed from the student's lives. At the same time, developing academic competencies, enables students to expand the types and level of activities they can master in an ETE program. However, despite nearly unanimous rhetorical support, the form, function and effectiveness of cross-curricular integration varies widely.

At the heart of these differences lies an ambiguous set of goals ranging from illustrating the relevance of core subjects, to becoming the primary teaching tool for new principles in mathematics, language arts and science. The goals which are selected for a particular program, are reflected in the form, quantity and assessment of the cross-curricular tasks. For instance, where the purpose is to illustrate the relevance of academic content, any identified use of mathematics, science or English can be considered adequate to qualify as cross-curricular integration. However, if the purpose is to reinforce the competencies students are gaining in other classes, then the ETE curriculum needs to integrate the application of those competencies into the curricular tasks. Finally, if the purpose is to introduce new concepts, beyond those students have encountered in the traditional core courses, then the curriculum and the teacher need to establish the foundation for that learning, and present it as a distinct part of the lesson.

In some cases the commercial curriculum includes explicit cross-curricular activities. Synergistics, Technology 2000 and Paxton-Patterson are among the commercial leaders in the field and provide good examples of the form cross-curricular integration can take. For instance, Synergistics' curricular materials include "Math Challenges" (word problems) in every module, however, they are generally not required. Technology 2000, Paxton-Patterson and a number of others include simple writing exercises. Yet, given the range of abilities and needs in a national market, many vendors explicitly limit their academic requirements, preferring instead to have teachers add whatever academic demands they see fit.

Currently, the mathematics demanded by the curricular tasks rarely requires more than rudimentary computations. For instance, many construction modules include material cost and quantity types of exercises that may include some multiplication but rarely anything more demanding. Indeed, the vast majority of the "mathematics" currently included are little more than exercises in measuring, and even those are often superficially pursued. Clearly the focus of the current math integration is primarily to illustrate its relevance to modern technology and not to build skills. However, even the relevance issues are often vague.

Rick B. has students report on how they used math in each module. He indicated that many of the math concepts are subtly introduced, and that students are employing them without even realizing it. For example, the robotics module uses "G and M" codes which employ the Cartesian coordinate system to position the robot. Students entering the code are actually using geometry even though they may not recognize it as math. While this suggests that modules may contain greater levels of math than are initially apparent, it is unclear what the students learn from its inclusion in this form.

The language arts components are also somewhat ambiguous. While they encourage "writing across the curriculum" the form and assessment approaches currently being employed raise questions about their effectiveness. Many of the written exercises required by the commercial curriculum are short one or two paragraph summaries of either the entire module or a particular exercise. In addition, while many programs require writing, no teacher I interviewed corrected writing assignments for spelling, structure or grammar. Indeed, most language arts assessments focused on content or volume rather than on the structure or use of language.

To some extent the effectiveness of the academic components seemed to be tied to their importance in completing the module's activities. For instance, in the computer-controlled milling module at Advance Tech, students have to develop a computer program to position a series of holes in their wood game-board project. This requires students to measure and manipulate the numerical information. In this module, students were persistent and eventually successful with the math. However, in modules such as the bridge design or construction model where students could successfully complete the activities without mastering the math, the students often skip it.

Other forms of cross-curricular integration such as team-teaching or common assignments, graded in both the ETE course and a core class, were non-existent as far as I could ascertain. This may be due to some of the structural limitations inherent in these programs.

The cost of the lab (averaging $120K for 16 modules and furniture), inhibits team-teaching since the facilities would have to be doubled to accommodate the additional students. Other forms of curricular-integration, such as cross-course assignments, are problematic for two reasons. First, the lack of a shared planning time for core and ETE teachers is a major barrier to increased curricular integration. When teams of core academic teachers meet for their common planning period, students are often assigned to exploratory and elective classes. This obviously presents difficulties in attempting to provide ETE teachers the common planning time needed for collaboration with the core teams. A second barrier exists by the very nature of an ETE course. In ETE courses, students are engaged in 16 different subjects at any one time, this makes collaboration with core courses difficult on any assignments beyond units which deal with technology generically.

Other challenges to cross-curricular integration have also emerged. In some schools ETE is a required course for all students, however, when ETE is an elective, it does not share a common group of students with other core classes. Therefore, a core teacher cannot assign work which requires access to the ETE lab. (However, the ETE teachers could conceivably require work based on units in core classes.) There are also issues of professional status between technology and academic teachers, willingness of academic teachers to become more project oriented and the need to fund additional use of the ETE lab.

For all of these reasons, cross-curricular integration is currently limited to some basic relevance building and short writing exercises. Clearly there are opportunities to expand these offerings. However, as long as collaboration is blocked by the current structural and interpersonal barriers, any attempts to include greater academic content will have to be borne by the ETE teacher alone. And as many of the ETE teachers attending the CITEA convention in Santa Clara noted, “There are only so many hours in a day!”

Conclusion

Explorations in Technology can provide an inspiring environment that engages students in a variety of learning activities. Alice K. describes the power of the program to keep students on task as “absolutely incredible”. These programs hold the promise of introducing students to the world of tomorrow. However, a number of issues have emerged which need to be addressed.

While process skills may be reinforced across subject areas the content learning is not. The lack of synthesis in most modular programs is an important shortcoming. Once the student leaves a module, the information is never accessed again. However, nothing in the module design prohibits cross-subject synthesis through projects or problem solving exercises.

Cross-curricular academic/technology integration is limited by both organizational barriers and the fact that “there are only so many hours in a day”. If the ETE teacher attempts cross-curricular integration in isolation, these barriers are likely to result in less integration than otherwise possible. Further study is necessary to find schools which are successfully integrating various disciplines and establish the basis of their success.

The potential superficiality of content learning is of particular concern. Here, the short time frames (5 to 10 days) of a module rotation may confound a variety of efforts. Ideally, curriculum materials provide “guided discovery” opportunities for students. However, given a lack of accountability and time to leisurely explore, students seem to be most intent on discovering the tools and methods involved in completing the activities. Even the highly prescriptive curriculum often fails to keep students from focusing on the activities at the expense of everything else.

The apparent motivating power of the module’s activities suggests that, where possible, content and activities should be defined in ways which inextricably link them together. For example if one wants students to know the names of various construction members, the instructions could require students to use texts and other materials in order to establish what size a “stud” or “header” should be in the model. This would require students to engage the content in order to accomplish the activity. This linkage seems central to the issue of how to increase content mastery in a way that motivates the greatest efforts.

The final issue is a philosophical one. In a world whose technology is changing so fast that 90% of the information used on the job in just ten years had not been created yet, should technology courses focus on content or process? If teaching students to be self-directed learners in a technology driven environment is the most important goal, instruction needs to shift towards more student-directed projects with embedded problem solving activities. On the other hand, a great deal more content can be provided in a highly structured program of step-by-step instruction. This central issue of how to integrate content and process, and where to sacrifice one for the other, is currently ambiguous and perhaps represents the single greatest barrier to fulfilling the potential of ETE courses.

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