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From the Editor

Of Melting Pots, Football Drafts, and Professor Jackson

It is known around the world that the United States is a melting pot of people from very diverse ethnic and cultural backgrounds. The melting pot analogy may be applied to the technology education curricula of the US as well. There is no national curriculum for technology education or any other subject in the schools. This should be no surprise to those who know about the history of the country since one of the fundamental principles of Jeffersonian Democracy is local control. Ultimately, local school districts decide what is taught, with some guidance from the states in which they exist.

The recently published *Standards for Technological Literacy* (ITEA, 2000) do not prescribe a curriculum for technology education. Thus, they allow for virtually an infinite number of ways in which a given school might meet them. Though some curriculum development efforts based on the standards are underway under the auspices of the ITEA, the resulting materials will serve only as exemplars and referents of how the Standards might be implemented. Most certainly, they will not be portrayed as the single, best approach.

As developmental work around the Standards continues to go on at the state and local levels, it will no doubt raise the awareness of the importance of technological literacy among constituencies never reached in the past. It could start a wellspring of interest in our field that has never occurred before. In the end, the dream that technology education would become a required experience for all students might be realized, duplicating what science achieved about a century ago.

The notion of technology education becoming a subject in the schools that is just as essential as English, social studies, mathematics, and science is exciting, indeed. There are some challenges, however, that we may wish to ponder. One is that we would have to deal with all the students in the school, not just those who elected to enroll in our courses. This should not be a significant challenge as long as we continue the hands-on, problem-solving approach that has reflected our ideals and represented our uniqueness throughout most of our history. We will need to pay more attention to the needs and interests of those we are not presently serving, but doing so will move us closer to realizing our general education beliefs.

A second challenge is that we will be held more accountable for what we teach — and for what our students learn. In my second year as a teacher, my school principal told me, “I do not care what you teach the children, Jim, just keep them busy and happy.” I naively thought his expression showed the high level of confidence that he had in me. Upon further reflection, I realized that there was really nothing that he could hold me accountable for in my curriculum, since no standards existed. Quite simply, without standards, he did not have to worry about what I was teaching and could devote his attention to other teachers and those required, albeit “more important,” subjects they taught.

It would be terribly unfortunate if a higher level of accountability led us to the dilemma in which so many teachers find themselves today where their entire teaching practice is driven by standardized, paper-and-pencil tests. The content of these tests become, in effect, a national curriculum. Since virtually no such tests for technology education in the US exist, though, we can start *tabula rasa*. We have the opportunity to develop authentic assessment means that focus on *doing* technology and solving technological problems with real tools and materials, not asking our students to answer a series of multiple choice questions for which a context is either absent or contrived. Fortunately we have some guidance in avoiding such a disastrous pitfall through the work of Richard Kimbell (1997) and others.

Perhaps the most perplexing challenge of the opportunity to provide technology education to all students is finding adequate numbers of teachers. We are currently in the midst of the worst shortage of technology education teachers ever. If technology education became a required school subject on par with science, my estimation is that the number of teachers would have to increase by a factor of at least five.

Discussions with faculty at other institutions in the US, along with my own experience, has led me to realize that the majority of students who choose to major in technology education are internal transfers from other programs in the university, often engineering. Relatively few begin their higher education studies in technology education. This is especially true at land grant universities. My best estimate is that, in the year 2000, there were only about eight students who began their first year in higher education as technology education majors across the entire state of Virginia. It is interesting to think about how our field might be different if the majority of our students started collegiate study aspiring to be teachers.

In the spring of each year, the National Football League in the US fills its player vacancies through a draft process. The young men chosen for the draft will begin a career playing professional football. In the year 2000, eleven football players were drafted from the state of Virginia. Generalizing from these data, it is more likely, then, that a student will become a professional football player than it is to start collegiate study as a major in technology education! I know through talking to my colleagues in other states that this situation may be even more dramatic elsewhere. When the ideal to which many of us aspire of having equal proportions of male and female teachers is considered, the odds are even more amazing.

There are approximately 1000 technology education teachers in Virginia. About half teach at the high school level. Collectively, these high school teachers see roughly 50,000 students each day. If each teacher recruited one student as a technology education major every three years, there would be about 150 students entering the universities each year, aspiring to become technology education teachers.

How many professional football players do you know? By the way, Professor Jackson, thanks to you are nearly 40 years overdue for encouraging me to consider a major other than civil engineering.

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Articles

An Assessment Model for a Design Approach to Technological Problem Solving

Rodney L. Custer, Brigitte G. Valesey, and Barry N. Burke

Education reform has focused increasingly on critical thinking processes, including problem solving and student assessment. Correspondingly, curriculum and professional development efforts are directed toward developing problem solving abilities through authentic learning and problem-based teaching methodologies.

The development of problem solving abilities is pivotal to technological literacy. Problem solving is a critical thinking skill necessary for addressing issues related to technology and for developing effective solutions to practical problems. According to the *Rationale and Structure for the Study of Technology* (ITEA, 1996), technologically literate persons "are capable problem solvers who consider technological issues from different points of view and in relationship to a variety of contexts"(p. 11). Waetjen (1989) cited problem solving as an important skill necessary for optimizing technological innovation and for developing technological literacy. Whether for economic competitiveness (National Commission on Excellence in Education, 1983), technical means for survival (Savage & Sterry, 1990), or to develop common sense knowledge of technology and how it evolves to meet human needs (DeLuca, 1992), problem solving is deemed an essential skill for a productive life.

With problem solving a major theme in technology education, there is a need for detailed assessments to determine how students solve problems and at what levels of expertise. This study sought to develop a model for assessing problem solving using a design approach to the study of technology.

Background

Problem solving is a complex set of thinking skills and human activities. Waetjen (1989), for example, proposed a problem solving model based on the work of Polya (1957, 1971) and Philpott & Sellwood (1987), involving defining the problem, reforming the problem, isolating the solution, implementing the plan, restructuring the plan, and synthesizing the solution. Pucel (1992) espoused problem solving as a technological method, where technology evolves to serve useful purposes of humans, based on processes of innovation.

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Savage & Sterry (1990) proposed a problem-solving model with the premise that humans depend on technical means for survival. They indicated that the problem solving process parallels the scientific method in science. In *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000), problem solving is defined as, "the process of understanding a problem, devising a plan, carrying out the plan, and evaluating the plan in order to solve a problem to meet a human need or want" (p. 255).

Problem solving occurs in various ways, depending on the task and the context. DeLuca (1992) identified several problem-solving processes applied to technology. These processes are troubleshooting/debugging, scientific process, design process, research and development, and project management. Custer (1995) classified problem-solving activities by complexity and goal clarity where design is a major subset of technological problem solving. Design, involving ideation, identifying possible solutions, prototyping, and finalizing the design, has become a predominant problem solving process in the technology education laboratory-classroom. The assessment model developed for this study focused on problem solving as a design-based process, guided by criteria and constraints. The model was not intended to be used with a singular approach nor incorporate a specific number of steps, but to be applied to many different methods, models, and practices.

Problem solving has been investigated in terms of thinking skills and critical activities. Halfin (1973) identified key mental processes used by technological professionals. They include defining the problem or opportunity, interpreting data, constructing models and prototypes, designing, testing, modeling, creating, and managing. Hill (1997) used definitions and examples developed from Halfin's mental processes to develop and field-test a tool for assessing students during technology education activities. The assessment tool was used to capture qualitative data concerning what mental processes were evidenced in duration and frequency during a modular instructional activity.

MacPherson (1998) explored factors affecting another form of technological problem solving, near transfer troubleshooting. He developed a rubric to assess critical incidents in various stages of problem solving activities associated with maintenance activities performed by technicians. This rubric contained critical incidents on a continuum from novice to expert levels. Findings indicated that years of experience, cognitive technical knowledge, and critical thinking were effective predictors of near transfer problem solving skills while cognitive style and problem solving style were least likely to predict problem solving abilities. Results indicated that novices and experts exhibited different patterns of behavior. The assessment rubric used in this study was based on the MacPherson study model.

Problem and Purpose

The *Technological Literacy Standards: Content for the Study of Technology* (ITEA, 2000) regards design as the primary problem-solving approach in Technology Education (p. 5). In design activities, students frequently collaborate to create design solutions through problem solving behaviors that require detailed and consistent evaluation. A need exists for assessment models to examine problem solving during and as a result of student activities. Evaluating the technological literacy of students depends upon assessment tools that measure levels of student performance and achievement individually and within groups. The goal of this study was to develop an assessment model that could be used to evaluate student problem solving performance in design activities.

Research Objectives

An assessment model was developed and field-tested to measure student problem solving performance in technological design activities. A rubric incorporating critical incidents in problem solving and expertise levels was central to the model. The model was intended to provide a framework for assessing technological problem solving in group and individual activities. The research questions for this study were:

1. What are the key components of a model to assess individuals and groups in problem solving activities? This study focused on creating and field-testing a model to provide guidance for developing comprehensive problem solving assessments.
2. What knowledge and skills do students gain from design-based problem solving activities? Since problem solving is a complex set of thinking skills, the assessment must be able to capture observable student behaviors that indicate critical incidents in design activities.
3. What factors (i.e., GPA, grade level, technology courses, mathematics and science grades, gender, personality preferences, and problem solving styles) affect problem-solving abilities of high school students? Since many technology education classes are made up of students of different backgrounds, preferences, and ability levels, this study sought to investigate the possible effects of various factors.

The methodologies and research instruments used in this study were designed to address these questions and to yield a model for assessing student problem solving in design activities. The next section details the methodologies used to develop and field test the model.

Methodology

Sample and Procedures

A combined quasi-experimental/descriptive design was used to explore factors affecting problem solving in a design activity. Groups of students were issued a design problem (i.e., to design a “school locker of the future”) and a set of design constraints. Constraints consisted of a time frame, limited funding, and use of physical, informational, and bio-chemical systems. The activity was conducted over eight hours, which was equally distributed over two days.

The study sample was comprised of two groups of high school students enrolled in technology education classes in two states. One group of students (n=12) was from a large, suburban, east-coast school district. A second sample (n=15) was from a small, rural, mid-western school district. This purposive sampling procedure was used to compare students from programs with contrasting philosophies and delivery systems. The east-coast students were accustomed to a design brief approach to technology education whereas the mid-western students' program used a more traditional lab and project-based approach. The two programs were selected to explore the effects of contrasting methods of delivering technology education (i.e., process-based, design brief approach vs. more content- and project-based approach). Students within each location were randomly assigned to groups of three individuals, which remained intact throughout the activity.

After an orientation to the activity (consisting of a brief discussion of design and problem solving, a verbal description of the design brief, and a period of clarification discussion), students engaged in a process of design clarification, design development, physical modeling, and evaluation (see Figure 1). Each group was issued an actual school locker unit and materials (i.e., markers, foam board, tape, scissors, cardboard, and hot glue guns) to use to construct a full-size mock-up of their design. All groups had access to a computer with an Internet connection and a telephone to use for research purposes or to contact suppliers.

At the conclusion of the activity, each group made a formal presentation, in which they described their mock-up and how effectively their design met the assigned constraints. Students were asked to explain their interpretation and refinement of the design constraints and describe the process that they used to research possible solutions to the problem.

Instrumentation and Data Collection

The researchers for the study designed two different rubrics. These were the *Student Individualized Performance* inventory (SIP) and the *Group Process* (GP) rubric. Both instruments were developed and validated by the research team in consultation with established experts in technological design and problem solving.

The *Student Individualized Performance* (SIP) rubric was developed to assess individual student performance in technological problem-solving situations. Based on a synthesis of the design literature, the researchers identified four major dimensions, which consistently were represented in various design and problem-solving models. These dimensions were Problem & Design Clarification, Develop a Design, Model/Prototype, and Evaluate the Design Solution. Each dimension was subdivided into three strands (see Figure 1), replicating the process used to identify the major dimensions. These dimension categories were reviewed by an expert panel with extensive knowledge of problem solving and design for conceptual accuracy. This process yielded substantial agreement with some minor revisions in terminology.

Each strand was rated on a five-point scale, from expert (5) to novice (1). To facilitate and refine the rating process, critical incident identifiers were developed for each performance level (Dyrenfurth, Custer, 1993; MacPherson, 1998). Figure 2 illustrates the critical incidents for Dimension #1. To optimize content validity, an expert panel familiar with technological design and authentic assessment reviewed drafts of the SIP. Based on their input, significant modifications were made to the conceptual framework for the rubric.[1]

A pilot test was conducted to refine the instrument and to conduct rater training. In the pilot test, one group of three students completed the design activity in a manner identical to the larger study. Following the pilot study, raters and students debriefed the experience. Based on the results, refinements were made to the directions given to students and to the design constraints. Critical incident statements were revised based on feedback from the two lead raters. During the actual study, the Cronbach Coefficient Alpha reliability was .78.

Dimension #1: Problem & Design Clarification
- Examine context and define problem
- Develop, clarify, and negotiate constraints and criteria
- Conduct research/gather pertinent information

Dimension #2: Develop a Design
- Generate and visualize possible solutions
- Select a design solution
- Plan and communicate design

Dimension #3: Model/Prototype
- Select resources
- Develop procedure
- Produce model/prototype

Dimension #4: Evaluate the Design Solution
- Test and critique solution against constraints
- Refine model
- Documentation/ Technical Reporting

Figure 1. *Dimensions and strands of the Student Individualized Performance rubric*.

During the two-day field test, two raters rated each student independently. These independent ratings were conducted in order to assess interrater reliability. Prior to actual data collection, raters were trained by the research team and by the lead rater who had conducted the ratings throughout the entire pilot-testing phase. The training consisted of an orientation to the design activity, a comprehensive analysis of the SIP rubric, and a briefing by the lead rater. The briefing included information about problems encountered and lessons learned during the pilot test.

One primary rater and one secondary rater were assigned to each three student design group. Each rater was responsible for rating one group of three students as a primary rater and a second group of three students as a secondary rater, thus rating a total of six students using the SIP rubric rating sheets. Immediately following the field test, each two-member rater team met to discuss

[1]Due to space limitations, only one dimension is presented in this article. The complete assessment rubric can be obtained by contacting Dr. Rodney L. Custer at custer@indtech.it.ilstu.edu.

Problem and Design Clarification

	Expert	Proficient	Competent	Beginner	Novice
Examine context & define problem	Poses pertinent questions for clarification; identifies and prioritizes sub-problems (within the larger problem); explores context.	Poses questions; Identifies sub-problems but does not prioritize. Ignores context.	Identifies key content; defines problem adequately. Asks some pertinent questions. Ignores context.	Expresses limited knowledge of context or problem area; problem is defined but needs clarification. Asks questions but not pertinent and too few. Ignores context. Exhibits some indifference or frustration.	Tends to hone in on wrong problem, isolated subset, or easiest part to solve. Begins to solve without clarification questions. Doesn't see context. Exhibits considerable indifference or frustration.
Develop, clarify, & negotiate constraints and criteria	Explains key constraints in detail; tried to negotiate or circumvent constraints; Gains clarification of criteria prior to solving problem or posing solutions.	Clarifies constraints in detail; expresses their relationship to the problem solution. Engages in some limited negotiation of the constraints.	Clarifies constraints and accepts them as presented and understood.	Recognizes constraints but seeks minimal clarification. Accepts as is. Clarifies constraints late in design process as failures occur.	Did not identify constraints or criteria; did not grasp the significance of constraints. Minimal grasp of (or concern about) constraints. Sees constraints as insignificant.
Conduct research/gather pertinent information	Consults several key sources; evaluates information; relates information back to problem and constraints. Exhibits refined search strategies. Researches sub-problems	Consults several key sources; uses observational techniques; cites references. Ignores sub-problems.	Uses search guides and locates at least 2 sources. Consults sources with some direction and/or organization.	Conducts very limited research. Restricted to easy to find and readily available resources.	Does not conduct research nor consult sources. Starts solving problem without information.

Figure 2: *Critical incidents for Dimension #1 of the SIP.*

their observations of individual students and to reconcile differences in ratings by consensus on a strand-by-strand basis. The final ratings for each student included two graded SIP rubrics (one per rater) and the combined SIP rubric (based on consensus between the two raters). In addition to analyzing the perceptual differences between raters, this process also enabled the researchers to examine the usability and effectiveness of the SIP instrument.

The interrater reliability was examined by correlating the total score ratings for both raters on each of the four dimensions (recorded prior to scoring difference negotiations between raters). Interrater reliability scores were low, ranging from .070 to .501. Based on an analysis of the rating process, two factors were believed to have contributed to these low reliability scores. First, while raters were briefed on the procedures and on the use of the rubric (including discussions of pilot testing feedback) some raters did not use the rubric in advance of the study. In retrospect, additional training of raters, including post-rating discussion of rating differences, should have been conducted in order to improve interrater reliability.

A second factor affecting the use of the SIP rubric as well as the overall assessment model for this study dealt with extracting individual performance and achievement from group process. Individual problem solving performance is a function of a complex set of factors, including content knowledge, problem solving style, and critical thinking ability. When these factors are embedded in group situations, the complexity is further elevated and assessment challenges are exacerbated. More research is needed to better understand how and in what ways individual performance is affected by group process.

For the purposes of this study, the negative effect of relatively low interrater reliability on validity was corrected by having the raters reconcile differences between ratings. These reconciled scores were used to statistically analyze the data. While this process enhanced the validity of ratings for this study, subsequent use of the model and SIP rubric should address the challenges associated with rating reliability.

SIP scoring consisted of assigning numerical values on a five-point scale (5=expert to 1=novice) to each of the twelve strands of the SIP. A single score was then computed for each dimension by averaging the scores for each three-strand set. An overall mean score was computed for each student by averaging the four dimension scores. Throughout this process, the combined (rater reconciled) SIP rubric scores were used.

Variables

The computed SIP values served as the dependent variable for the study. Based on the literature review and the perceptions of the researchers, a set of independent variables was also identified. These consisted of program type (east coast vs. mid-west), technology education experience (number of courses taken), grade level, mathematics and science achievement scores (course grades), personality type (measured by the Myers-Briggs Personality Inventory), problem solving style (measured by the Problem Solving Indicator), and gender.

The Myers-Briggs scores were grouped into four categories, consistent with established scoring and interpretation procedures. These categories consisted of action-oriented innovators (extravert-intuitive), action-oriented realists (extravert-sensing), thoughtful innovators (introvert-intuitive), and thoughtful realists (introvert-realists).

Problem-solving style was measured using an adapted version of the standardized Problem-Solving Inventory (PSI-TECH) (Wu, Custer, & Dyrenfurth, 1996). This paper and pencil, self-reporting instrument is designed to measure factors including problem-solving self-confidence, approach-avoidance, and personal control. Statistical analysis consisted of descriptive statistics, analysis of variance and correlation.

Findings and Discussion

Due to the exploratory nature of the study, descriptive data analysis procedures were used. These procedures were also judged to be appropriate due to the relatively small sample size and the purposive sample selection. While these limitations disallow the use of statistical inference, a descriptive analysis nevertheless provides a useful preliminary basis for more extensive research.

As stated previously, design involves a complex set of cognitive processes. The four rubric dimensions embody this complexity and represent different activities. When the Dimension Total scores are compared, it is not surprising that modeling/prototyping scores were the highest (See Table 1) since historically, technology education programs and curricula have concentrated on making products and implementing designs. Given the design focus in the *Standards for Technological Literacy*, there is a need to emphasize the preliminary and preparatory aspects of the design process (Dimensions #1 and #2) as well as the more analytical, evaluative component (Dimension #4) in technology education curriculum and instruction. One independent variable was program type; over the past decade, programs in the east coast district concentrated on design more than programs in the rural mid-west district. The results of this study are inconclusive since mean score differences between the two samples are minimal and the differences could be a function of rater differences between the two locations. Note that in order for statistically meaningful comparisons of programs to occur, the treatments would need to be more controlled and the samples would need to be much larger.

One purpose of this study was to conduct a preliminary analysis of design data according to achievement, as measured by overall GPA and mathematics and science achievement. Table 2 shows correlational values that emerged from the data analysis. Note that correlational effect sizes in the range of .30 and .50 are considered to be significant at the "medium" and "large" levels respectively for behavioral science research (Cohen, 1988). Thus, the pattern of results suggests some interesting relationships between technological design performance, GPA, and science achievement. Note the relatively low scores for mathematics as well as the low associations across the variables for Dimensions #1 and #2. The association between science achievement and Dimension #4 hints at a possible focus on analytical skills; specifically, a predisposition for

Table 1
Program Type by Problem Solving Dimension

	East-coast Sample			Mid-west Sample			Dimension Sample		
Dimension	*n*	*m*	*SD*	*n*	*m*	*SD*	*n*	*m*	*SD*
#1 Prob. & Design Clarification	12	2.7	.64	14	3.0	.44	26	2.8	.55
#2 Develop a Design	12	2.5	.58	14	3.0	.49	26	2.8	.57
#3 Model/ Prototype	12	2.9	.79	14	3.3	.31	26	3.1	.60
#4 Evaluate the Solution	12	2.4	.36	14	2.3	.57	26	2.4	.48
Sample Total	12	2.6	.50	14	2.9	.29			

interpreting experimental results (science) rather than solving well structured and prescribed problems (mathematics).

Even though these are preliminary findings, the results suggest that the relationship between mathematics and science achievement on the one hand and performance in technological design may be differential and complex. Also, some aspects of design on the other may be more useful than others in implementing “inquiry-based” learning in mathematics and science. The complexities of these factors provide rich opportunities for additional research.

Student performance was also analyzed by gender (see Table 3). While the total scores were nearly identical, there are differences in Dimensions #3 and #4. The comparatively higher Model/Prototype score for males corresponds somewhat with gender stereotypes, where males are often considered more comfortable with constructing/making activities. The elevated solution evaluation scores for females represents an interesting contrast, with females demonstrating a comparatively stronger analytical ability related to the quality of the design and prototype. While these results are far from conclusive, they warrant further study since gender differences related to interests in and participation with technology are not well understood.

Table 2
Correlational Analysis for Design Dimension GPA, Mathematics Achievement, and Science Achievement

Dimension	GPA	Mathematics Achievement	Science Achievement
#1 Prob. & Design Clarification	.162	-.184	.133
#2 Develop a Design	.244	-.055	.186
#3 Model/Prototype	.260	.194	.335
#4 Evaluate the Solution	.287	.200	.428
Total Score	.342	.118	.398

Table 3
Student Design Performance by Gender

	Male			Female		
Dimension	*n*	*m*	SD	*n*	*m*	SD
#1 Prob. & Design Clarification	20	2.8	.53	2.9	2.9	.67
#2 Develop a Design	20	2.8	.58	2.7	2.7	.56
#3 Model/Prototype	20	3.2	.52	2.9	2.9	.82
#4 Evaluate the Solution	20	2.3	.50	3.4	3.4	.42
Sample Total	20	2.8	.39	2.7	2.7	.49

Several patterns emerged when problem-solving performance was analyzed according to personality type. As shown in Table 4, the highest percentage of the sample (nearly 50%) were in the action-oriented innovator category. While overall performance scores were slightly higher for this group, the groups were essentially identical. These results make intuitive sense, since innovative, action-oriented individuals could be expected to enroll in courses dealing with technological design. Perhaps more hopeful is the indication that while creative problem solving activities may appeal to certain personalities, actual performance was very similar across all four personality types.

When the data are examined on a dimension-by-dimension basis, the most striking difference in personality types is with the thoughtful realists, who rated substantially lower on the first two dimensions. While factors other than personality type could certainly have contributed to these results, it is possible that individuals with this personality type may perform less well than others during the planning stages of design activities.

The potential implications for teaching and learning in technology education classrooms are important. These findings suggest that problem-solving performance in design activities may not be a function of personality type. What is encouraging from this study is that students of different personality types can participate and achieve in design activities on a relatively equal basis. Conversely, what is discouraging is what could happen to group and individual performance when personality types are deliberately homogeneous. Given the emphasis on teams and collaborative activity in education and industry, this represents a valuable area for additional research.

Table 4
Myers Briggs Personality Type by Problem Solving Dimension

	EN		ES		IN		IS	
Dimension	*m*	SD	*m*	SD	*m*	SD	*m*	SD
#1 Prob. & Design Clarification	3.0	.55	2.9	.40	2.8	.68	2.4	.55
#2 Develop a Design	2.9	.66	2.8	.30	2.7	.77	2.5	.51
#3 Model/Prototype	3.2	.70	3.1	.60	3.0	.34	3.1	.69
#4 Evaluate the Solution	2.5	.46	2.3	.73	2.1	.35	2.4	.07
Sample Total	2.9	.46	2.8	.42	2.6	.31	2.7	.40

EN: Action-oriented innovators (*n*=11) IN: Thoughtful innovators (*n*=4)
ES: Action-oriented realists (*n*=6) IS: Thoughtful realists (*n*=5)

Another trait that was examined in this study was the relationship between problem-solving design performance and problem-solving style (as measured by an adaptation of Heppner's *Problem-Solving Inventory* (PSI). The PSI is designed to measure three components of efficacy in problem solving situations: self-confidence (extent to which individuals believe they can successfully solve problems), approach-avoidance (tendency to actively pursue problem solutions in a timely manner), and personal control (extent to which individuals feel like they are in control of problem situations). The validity and reliability of a technological version of the instrument (PSI-TECH) were established in two previous studies (Wu, 1996; MacPherson, 1998) and were found to be nearly identical to the original standardized instrument (e.g., Cronbach's Alpha ranging from 0.71 to 0.88). The primary difference between the original PSI and the PSI-TECH is that the PSI-TECH focuses specifically on technological problem solving situations.

Table 5 contains descriptive statistics for this study's sample. Note that the possible point values are different for each efficacy component, thus a major part of the differences in mean score values across the three components is a function of differences in the metric employed. Also, PSI scores are inversely related to the trait, with high scores representing a reduced presence of a given trait. For example, a high numerical self-confidence score would indicate low levels of self-confidence.

In order to meaningfully interpret PSI-TECH scores, this study's data were compared with those obtained in the two previous studies, using the identical instrument (see Table 6). The Wu (1996) study focused on a sample of 300 students from five different mid-western universities. The sample was evenly distributed across the humanities, technology education, and engineering. The technician sample (MacPherson, 1998) was comprised of 15 professional maintenance technicians in light manufacturing and service industries.

Table 5
Problem-solving Style (PSI-TECH)

Efficacy Component	Pts. Poss.	*m*	SD	Min. Score	Max. Score
Self confidence (SC)	66	24.23	6.80	13	37
Approach Avoidance (AA)	96	50.12	12.00	28	81
Personal Control (PC)	30	14.92	4.47	5	23
Total	192	89.08	20.20	53	129

n=26

The results of this study indicate that overall problem-solving style scores for this study's high school student sample compare favorably to the university level technology education group, with both being considerably higher than the university level humanities majors (note that lower scores represent higher levels of the trait). Predictably, efficacy levels for the professional level, adult technicians were noticeably higher. When the results of the three studies are compared on a trait-by-trait basis, a similar contrast can be observed for self-confidence. There was somewhat less contrast with personal control, where the high school students actually felt a stronger sense of control in technological problem solving situations than did university level technology education students (and considerably more than humanities majors). Approach-avoidance scores ranged from technicians (highest) to high school students (lowest) with university technology education majors approximately half way between.

In addition to providing normative data for this study, the prior studies also yielded useful calibration reference points, with technicians representing the "expert" end of the continuum and humanities students representing "novice" end. While additional sampling and research is needed to calibrate the instrument more accurately, this process provides a preliminary and reasonable approach for understanding where this study's sample fits within a larger context. Using this approach to calibration, the high school sample tends to resemble the novice end of the spectrum for efficacy with technology. These findings have important implications for learning and teaching related to technological design and problem solving. Educational research has repeatedly shown that motivation, performance, and achievement are closely interrelated. The technology education profession could benefit from additional study of how efficacy factors influence (and are influenced by) student performance in design activities.

The PSI-TECH efficacy scores were then correlated with the problem solving dimension data in order to explore the relationship between efficacy and problem solving performance. Based on the data in Table 7, students were generally most efficacious on Dimension #1. These findings are somewhat surprising given the performance results in Table 1 above, where student performance was highest on Dimension #3. It could have been expected that the higher PSI-TECH scores would be most closely associated with areas of strong performance. While correlation values are moderate, the strongest associations clustered along the problem clarification dimension. This could indicate that students tend to feel more comfortable with problem clarification as a more structured aspect of the design process than they do with more abstract and creative aspects of design.

Table 6
Mean Scores for Comparative Studies (PSI-TECH)

	University Level Students (Wu study)			
Efficiency Component	Technology Education Students	Humanities Students	Technicians (MacPherson study)	Sample for this study
Self confidence	24.34	27.79	16.64	24.23
Approach Avoidance	43.49	50.59	34.14	50.12
Personal Control	15.36	17.54	11.43	14.92
Total	83.19	95.92	63.71	89.08

Table 7
Correlational Analysis of PSI-TECH vs. Problem-solving Dimension

Dimension	Self Confidence	Approach Avoidance	Personal Control	Total
#1 Prob. & Design Clarification	.365	.455	.394	.486
#2 Develop a Design	.297	.150	.338	.262
#3 Model/Prototype	.087	.086	.314	.048
#4 Evaluate the Solution	.295	.142	.418	.265
Total Score	.306	.122	.478	.277

To further refine the analysis of student characteristics, the data were also analyzed by grade level (see Table 8). Note that 12th grade student performance was highest, particularly on Dimensions #2 and #3. This makes sense given the maturity and, in some cases, additional experience with technology classes. Further research is needed to better understand the interesting and complex relationship between students' involvement in the design process, their experience and maturity, and the extent to which they feel confident and in control of the process.

Overall group performance was assessed in order to evaluate the quality of group dynamics and performance. As shown in Table 9, the rubric included items specific to technological design as well as other items that dealt with more

Table 8
Student Design Performance by Dimension

	Grade 9		Grade 10		Grade 11		Grade 12	
Dimension	*m*	SD	*m*	SD	*m*	SD	*m*	SD
#1 Prob. & Design Clarification	2.6	.69	2.7	.93	2.9	.49	2.9	.40
#2 Develop a Design	2.5	.73	2.6	.83	2.8	.37	3.1	.76
#3 Model/ Prototype	3.1	.86	3.0	.89	3.1	.56	3.3	.42
#4 Evaluate the Solution	2.6	.25	2.4	.55	2.4	.51	2.1	.43
Sample Total	2.7	.61	2.7	.70	2.8	.30	2.9	.40

general process skills. The lowest group average score was on item #10, the item that is most specific to technological design. This tendency to prematurely select design solutions also occurs with individuals. More research is needed to explore the extent to which group involvement either exacerbates or reduces this "rush to judgment" tendency in design situations.

The findings of the study indicate that, while some areas of performance are strong, other areas could benefit from additional intervention and focus. While the generalizability of these results is limited, the findings suggest that the profession could benefit from more instruction and assessments on teamwork and group processes. This is especially important given the emphasis on group process in the *Technological Literacy Standards.*

Table 9
Group Evaluation Rubric

	m	*SD*
1. As a whole, the group was flexible and adaptable	4.42	0.70
2. All members of the group contributed actively to the process	4.23	0.78
3. The group was able to incorporate diverse personalities and ideas	4.19	0.97
4. The group had the ability to resolve adversity (ideas that didn't work, frustration, etc.)	4.06	0.79
5. There was a good balance between group and individual work	3.92	0.97
6. All members contributed creative ideas to the process	3.79	1.03
7. The group was able to re-energize when the energy level dropped off	3.38	0.64
8. The group was able to critique its own work	3.19	0.47
9. The members achieved an appropriate balance between leadership and follower ship	3.01	0.65
10. The group generated many new ideas rather than prematurely selecting a single solution	2.87	0.81

5 – Absolutely true of this group
4 – Described the group for the most part
3 – Description fit the group about half of the time
2 – Only marginally describes the group
1 – Does not describe the group at all

Conclusions and Recommendations

Problem solving in technological design activities can be identified as a set of observable behaviors on a performance level continuum. These behaviors can be captured on an assessment instrument and can provide valuable clues to a student's critical and creative thinking abilities. What is more difficult to discern are the effects of factors such as GPA, math and science achievement, gender, and personality type, on student performance in design activities. While the results revealed some effects, they are far from conclusive.

The rubric instrument designed for this study identified key indicators of problem solving. This study revealed the complexity of observing and rating several students at the same time and the challenges associated with untangling individual from group performance. While the rubric was useful as an assessment tool, additional refinement will be necessary for laboratory-classroom application, particularly in probing the actual thought processes of students during the design activity. The experience in this study, however, suggests that the SIP is useful as a research tool.

This study was designed to provide a model for assessing students as they engage in problem solving in design activities. The research methodology presented many challenges from identifying key student behaviors to examining individual as well as group effects. Translating the model into practice poses additional challenges for researchers and practitioners. The researchers offer the following recommendations for further research:

- Further validate and refine critical incidents.
- Control for selected variables in future studies to establish possible effects and interactions.
- Explore ways to capture understanding of technological content as part of the problem solving process.
- Examine the role of group process in assessing individual performance.
- Develop assessment instruments from the model that can be readily used in the laboratory-classroom.
- Develop mechanisms for assessing selected students over an extended time period to determine to what extent their problem solving performance changes as a result of doing design activities.
- Examine how teachers currently assess students and what critical incidents they identify in their assessments.

This study presented an avenue for research that can provide valuable information concerning student problem solving performance in design activities. Appropriate assessment measures will provide in-depth information concerning student performance and levels of problem solving expertise. Such assessments will contribute to better monitoring of student progress and possible identification of future innovators, industrial designers, engineers, and technologists.

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Problem Solving with an Icon Oriented Programming Tool: A Case Study in Technology Education

Jari M. Lavonen, Veijo P. Meisalo and Matti Lattu

Introduction

In 1995, the authors started the Empirica Control for Technology Education (*ECTE*) project in the Department of Teacher Education at the University of Helsinki with the purpose of widening the possibilities for creative problem solving in technology education. First, an icon-oriented visual programming tool was developed to teach computer control technology, along with an appropriate computer interface. Authors developed the new programming tool to minimize the need for direct guidance from the teacher and to reduce the need for rote memorization of programming rules. It was also designed to allow for constructive and creative activities by the students. Along with the software and hardware, handbooks for creative problem solving in control technology were written and in-service training was organized to support teachers in their efforts to develop creative problem solving through technology education programs in Finnish comprehensive schools.

The development of this new computer control system led to an interest among the authors in finding out how pupils learn the basics of control technology and programming and how they creatively solve problems within the context of computer control.

Creative Problem Solving

The terms “problem” and “problem solving process” have been defined in many ways (e.g.,McCade, 1990; Fisher, 1990, p. 100; Higgins, 1994, pp. 20-21). For example, the terms “designing,” “trouble shooting,” “solving textbook problems,” and “experimenting” are sometimes used interchangeably with “problem solving”. In this study, the focus was on creative problems, meaning ill-defined and multifaceted real world problems that pupils seek and find in their environment (cf., Higgins, 1994, pp. 35-57; Lewis, Petrina & Hill, 1998). Therefore, it was important to analyze the whole environment; one must be aware that a problem must exist before it can be solved. When problem solving is creative, ideas or products produced during the problem solving process are original and appropriate (Fisher, 1990, pp. 29-31). Effective problem solving is a process that consists of various stages. These may include formulating the problem, recognizing facts related to the problem, setting goals, ideating or generating alternatives, evaluating ideas, choosing the most promising solution, and the testing and evaluating of the problem, recognizing facts related to the problem, setting goals, ideating or generating alternatives, evaluating ideas, choosing the most promising solution, and the testing and evaluating of the

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solution (see Table 1 below; Fisher, 1990, p. 39; De Luca, 1993; Higgins, 1994, p. 19). The problem solving process is not linear and does not strictly follow any particular rules. Structured approaches often miss the whole point of creative problem solving.

Because of how the human mind works to create new ideas, pupils need to apply thinking that is critical, systematic, analytic, and vertical as well as thinking that is creative, intuitive, divergent, and lateral in their problem solving. The emphasis in modern education has often been exclusively on critical thinking. Of course, even critical thinking is needed in problem solving, especially in the recognition of facts related to the problem and in the evaluation of the ideas. The need for various special approaches to promote creative thinking arises from the limitations of the behavior of the mind as a self-maximizing memory system (de Bono, 1970). Therefore, various idea generation techniques or ideation models are valuable (Smith, 1998). Consequently, the outcomes of creative problem solving activities depend on the creative processes and ideation techniques that are learned and applied. Furthermore, there are attitudinal (interest, motivation, and confidence), cognitive (knowledge, memory, and thinking skills), and experiential (familiarity with content, context, and strategies) factors that influence problem solving processes (Fisher, 1990, p. 112). For example, non-judgmental, positive feedback and the acceptance of all ideas, even absurd or impractical ones, are important in all creative group processes for generating non-trivial alternatives (Higgins, 1994, p. 119). In Table 1, some key features that are typical of creative group processes are presented (cf. Runco & Okuda, 1988; Fisher, 1990, pp. 97-129; Higgins, 1994).

Various ways of emphasizing (creative) problem solving in a learning environment have been suggested (Grabinger, 1996, p. 665; Dooley, 1997; Hill, 1999). A common feature of these approaches is to place pupils in the midst of a realistic, ill-defined, complex, and meaningful problem, with no obvious or "correct" solution. Pupils act as professionals in small groups and confront problems as they occur, with no absolute boundaries, insufficient information, and a need to settle on the best possible solution by a given date. In other words, learning is authentic (e.g., Lafer & Markert, 1994) in that it involves real-world problem solving situations and is self-directed and reflective. This kind of problem-centered approach empowers the pupils to take responsibility for their learning by allowing them to define what they need to learn and to identify the resources needed. The teacher's role is that of a facilitator in the learning process.

Sellwood (1991, pp. 4–6), De Luca (1993) and Williams and Williams (1997) argued that creative problem-solving activities are an integral part of design and technology education, in contrast to instruction that is a step-by-step process, engaging students in reproducing artifacts in an environment dominated by the teacher. Some researchers suggest even more forcefully that creative problem solving is the core content and an important teaching method of design and technology education (Lee 1996; Wu, Custer & Dyrenfurth, 1996). Therefore, in the ECTE project special attention was given to learning materials

Table 1.
Key features typical of creative problem solving in groups.

Features of creative problem solving	Indications of the features
1. Suitable atmosphere for creative problem solving	Group members: · Trust one another and believe in the power of group work. · Are motivated, active participants and apply their creativity to the problem. · Have a positive and constructively critical attitude about the ideas presented by other group members.
2. Knowledge of the problem solving process and its application in fostering creativity.	Group members: · Identify and focus on essential aspects of the problem. · Recognize and find the facts related to the problem. · Set goals and have a vision for solving the problem. · Know and apply ideation models and are able to generate new, original ideas. · Appreciate the ideas of others and can provide positive feedback, resulting in further development of the ideas. · Think intuitively, creatively, and divergently, as well as think systematically, critically, and analytically. · Know and use techniques for evaluating ideas · Separate ideation from evaluation. · Put ideas into practice through modeling, evaluation, and further development.

that would promote creative problem solving in a group and to various ideation techniques applicable to control technology projects.

The Programming Tool

Various investigations have been conducted in learning environments where computers, interfaces, and construction kits or building blocks are used in control technology for hands-on projects that require problem solving in groups (Parkinson, 1999). Several studies have been conducted in the Lego/Logo (Lego TC Logo) learning environment. Their aim has typically been to find out about the learning of various skills, qualities of social interaction, problem-solving approaches, and the attitudes of pupils towards their study (Lafer & Markert, 1994). It has been emphasized (e.g., Järvinen, 1998) that the syntax sensitivity of the Logo language makes it cognitively complex, resulting in programming tasks that are difficult and frustrating for pupils. Moreover, only Legos can be connected to the Lego interface and the selection of sensors is rather limited. Although much work has been done already, more development work and research are needed to ascertain the effects of microcomputer-assisted approaches to teaching control technology in various learning environments.

In the ECTE project, the authors developed the *Empirica Control for Windows 95*, an icon-oriented programming tool. The hypothesis of the developers was that a visual programming language based on icons makes programming easier than with text-based languages. When programming with languages like *Visual Basic* and *Logo*, one has to be very careful with the program structure and the spelling of the code words. With these types of languages, the skill of using the tool, not problem solving, often becomes the main focus. With Empirica Control, the user simply drags icons to a program diagram instead of typing programming code. This visual approach to the language makes the programming process much more concrete. The user simply chooses command icons by pointing to them with a mouse and clicking; hence the icons are linked with lines to form a structure like a flow chart.

Several developers have used the "mini-language" approach (e.g., Brusilovsky, Kouchnirenko, Miller & Tomek, 1994) whereby a pupil learns to program using the mental analogy of the control of an "actor" in the programming process. This sort of approach was applied in the Empirica Control system. While running a program, a blue ball moves along the flow chart, indicating which of the commands the computer is currently processing. The pupil can imagine that writing the program is the same as writing rules for that blue ball. The blue ball is analogous to an actor in the context mentioned above. All the parameters for commands are set from dialogue windows, which means that few details have to be memorized. The Empirica Control gets data from the environment via the Empirica I/O Interface connected to the RS-232 serial port of a computer. The interface has been designed especially for educational institutions. For example, its digital outputs are able to deliver currents up to one ampere, which make it suitable for the direct control of DC motors. In addition, over 20 different sensors can be connected as analog inputs. Thus, the system has the versatility to allow for a wide variety of solutions to a given problem.

A user's guide (Lavonen & Meisalo, 1997a) and a handbook called *Technology* (Lavonen & Meisalo, 1997b) were written to help teachers organize learning environments in which pupils can learn the basic commands, principles, and skills needed to operate the Empirica Control. The first section of the handbook is reference material that includes information about the basics of programming with the Empirica Control. The second section explains the basics of technological systems, such as the concepts of open versus closed loops and the elements of input, process, and output (see Hacker & Barden, 1988, pp. 47-56). The second section also includes examples, which express the essential role of control technology in home, industry, and society. The third section deals with broader projects with special attention given to creative problem solving in general as well as practical problem-solving models. Furthermore, some idea generation techniques are introduced. The general aim of this section is to help the pupil to discover how the learning environment can help in planning, designing, constructing, programming, testing, redesigning, and evaluating.

It is obvious that more research and development efforts are needed to better understand how to introduce learning environments with a problem-solving approach that are effective in technology education programs (Lee, 1996). Creative problem solving has been the leading principle in the design of learning environments and it was a significant influence on the research goals of this study. The main purpose was to evaluate the nature of the pupil's creative problem solving processes in a learning environment equipped with learning materials developed in the ECTE project. The principal research questions were:

1. Is it possible to organize problem-centered and creative learning in a learning environment using the software and hardware developed in the ECTE project?
2. What are the indications of problem-centered learning in the learning environment?
3. What are the indications of pupils' creative roles and behavior in problem solving within control technology projects?

The Empirical Study

This study can best be described as a qualitative case study since the researchers selected for closer examination a typical example from a small number of other examples. The case study approach was chosen because it gives the best possibilities for closely following the problem-solving process in a particular learning environment, and consequently to raise questions for further research and development. Case study research "seeks to understand specific issues and problems of practice" (Merriam, 1988, p. 23) through a detailed examination of a specific group of people, a particular organization, or a selected activity. Naturally, such an approach does not allow any broad generalizations to be made. However, this restriction was accepted at this explorative stage of the research and development process.

The teaching experiment

The experiment was organized at a teacher training school located in a metropolitan area in Finland during the spring term of 1998. A total of 34 eighth-grade (14-year-old) pupils in three separate groups attended an elective technology course arranged by a science teacher in the school. The technology theme was new to all the pupils. The pupils worked in three study groups, in randomly assigned pairs, for 20 hours. A computer equipped with the Empirica Control, the *Empirica Control Guidebook*, a *Lasy* robotics kit, a set of cables, and a set of lamps were available to each pair.

A male teacher with considerable teaching experience in science was trained to use the Empirica Control software and the Empirica Interface during a three-day in-service training workshop. During the workshop, the teacher also became familiar with the technology theme to be used in the experiment. After the workshop the teacher studied the *Empirica Control Guidebook* (Lavonen & Meisalo, 1997a) and a technology education handbook (Lavonen & Meisalo, 1997b). He also practiced with the software and hardware. The basic principles of creative problem solving were familiar to the teacher beforehand. Before the teaching experiment began, the teacher discussed and planned the experiment with one of the researchers.

The course began with a two-hour introduction during which the main operations of the Empirica Control system were presented. In the second period, lasting 10-12 hours, the pupils solved technological problems using the system. The teacher and other pupils, as well as the user manual, provided support. During this period, practical tasks were selected to familiarize pupils with various programming structures such as if-then and loop structures, as well as typical technological processes such as automatic switching. For example, the project introducing automatic switches was formulated in relation to an everyday situation, by telling a story of how tenants of an apartment building constantly forgot to turn the lights off in the basement. The pupils had to develop various solutions to this authentic, open-ended problem. Other projects included designing a rotating advertising booth, an automatic gate, an elevator, and a robot. During the last six to eight hours of the teaching experiment, the pupils also had the possibility to create problems of their own choosing.

Collecting the data

To ensure the validity and credibility of the research, various approaches to applying triangulation in the data acquisition process were used (Cohen & Manion, 1986, pp. 254-271). This involved video recordings of the pupils' problem-solving processes, observer's field notes, teacher interviews, and documentation of the pupils' computer program files.

The field notes were written in the classroom and completed immediately after the field research according to the principles of non-participant observations (Cohen & Manion 1986, pp. 120-147). Observation as a research method has been criticized because of its subjectivity and because it allows researchers to observe only the external behavior and actions of participants. Therefore, the researchers observed and videotaped the pupils in three separate groups so that inconsistent findings could be determined. The videotapes allowed the activities of the pupils to be observed several times and were a principal means of collecting data. Though videotaping can affect the students' activities, the teacher felt that it was not a factor in this experiment. Available resources limited the recording to one hour in each of the three groups. One of the researchers, in consultation with the teacher, selected representative pairs of students for video recording from each of the three groups. The field notes confirmed that the activities and success of the selected pairs did not differ from those of the majority. To get the most relevant data for this study, the recordings were made during the second period, a time when the students worked on small open-ended problems suggested by the teacher. All computer program files created by the pupils were collected.

One of the problems that the students were given was to "Create a program and the wiring, which turns the fan on when the temperature is over 27ºC and the button is pushed. The system should turn the fan off when the temperature drops below 27ºC or the button is released." Two example solutions to this problem are shown in Figure 1.

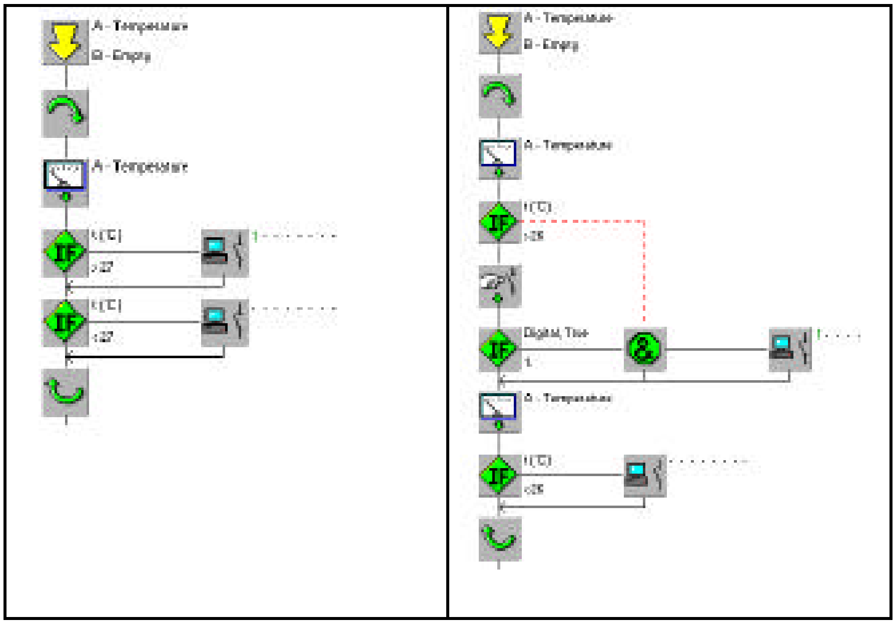

Figure 1. Sample student solutions to programming problem.

The teacher was interviewed using an unstructured interview (Cohen & Manion, 1986, pp. 291-314). Notes were written during the interview and finalized immediately after its completion. The interview provided information on the goals of the course and the teacher's behavior during the experiment. Furthermore, the observations that were unclear or confusing were validated through the interview. It was also possible to compare the videotaped examples to the remainder of the course. A qualitative interview outline was prepared beforehand to support the interview and reduce interview subjectivity. The outline consisted of the following five questions:

1. What goals did you have in mind when you planned the technology projects?
2. Ask about problem-centered learning and creativity if the teacher does not otherwise discuss them.
3. What do you think about reaching the goals?
4. Ask about achieving the goals considering the knowledge and various skills (creative, programming, …) of the students.
5. Can you please analyze a) your own and b) pupils behavior during the project?
6. What do you think about the learning environment used in this project?
7. Ask about the physical (software and hardware) and pedagogical nature of the learning environment and how a teacher changes the environment during the course or between the courses, if the teacher does not otherwise discuss them.

The transcribed field notes and the teacher's interview covered nine standard pages.

Analyzing the data

Preliminary data analysis was started immediately after the initial data were collected. However, the comprehensive analysis was performed after all data collection was completed. The intensive data analysis began by first reviewing the purpose of the study: to find positive and/or negative indications of pupils' problem-centered learning and indications of pupils creative roles and behavior in problem solving within control technology projects. After that, the researchers read the field notes, reviewed the teacher interview record, and observed the videotapes twice, while discussing preliminary findings with each other. One researcher recorded the main verbal and nonverbal events and the other researchers validated the notes on the basis of the video recordings. These data enabled the researchers to observe patterns, propose explanations, develop categorical definitions, and to create more differentiated and integrated text (Huberman & Miles, 1994, p. 433).

The data analysis was structured into categories and subcategories according to the main objectives of the study. The first category, problem-centered learning and its environment, was divided into four subcategories:

- The nature of problem-centered activities
- The nature of pupils' activity in a learning environment
- The nature of teachers' activity in a learning environment
- The nature of how students learn computer programming.

The second broad category was organized according to the key features typical of creative problem solving, as presented in Table 1. Further information from the creative process was obtained by analyzing program files created by the pupils.

Results

During the teaching experiment, the pupils successfully solved their control technology problems with the new programming tool and hardware developed by the ECTE project. What follows are the positive and negative indications of pupils' problem-centered learning and indications of creative processes are described based on the video recordings' notes, the field notes, and the teacher interview. Representative responses are presented below.

Problem-centered approach

As evidenced from the notes taken on the videos, it was apparent how the pupils solve technological problems with the programming tool without formal teaching: "Although the pair (A) faced a problem, they still continue to work on the task". The field notes revealed how pupils acted as professionals in the small groups and agreed on the assignment of tasks: "The pairs assigned activities, e.g., one works with the interface and Lasy kit and the other programs". The pairs worked in various ways. In some groups one student mainly worked on the program and the other constructed the models. In other groups, students changed their roles as they worked on the problem. Apparent in the videos and notes was how intensively the pupils were engaged in problem solving: “When a pupil from pair C came to see how pair B was succeeding, the latter continued their work without any interruption.” As a confirmation, the teacher spontaneously remarked in the interview: “The work was problem centered all the time.” One central deficiency in the problem-centered approach was that the teacher set the starting point of the projects. On the other hand, the notes stated: “In addition to the given problems, pair (B) varied and extended its solutions”.

It was clearly seen in the videos that the teacher had mainly taken the role of a questioner, attempting to clarify the pupils’ ideas. The teacher asked questions like: “What are you doing? What is your aim? What have you done up to now? How is your model and program working? What are the inputs and outputs in your program”? Though this approach worked with some students, it did not with others. In some cases, the teacher seemed to give direct advice on how to edit the program, taking away the opportunity for the students to solve the problem on their own.

The notes and videos showed that during the problem-centered projects, it was reasonably easy for the students to become familiar with the programming tool. The teacher confirmed this: “The students learn quite easily to setup the program, start programming, and make the connections to the interface. The visual programming tool helps in programming.” On the other hand, if the pupils had been taught the basics of programming ahead of time and if the handbook had been introduced, their autonomy in solving the problems would likely have increased. The lack of planning and programming skills appeared in both the observers’ notes and the teacher’s comments: “Low-achievers especially have problems in long-term independent effort requiring planning and programming.” The notes from the video also revealed that the pupils did not find the facts they needed in the handbook: “A pupil (in pair A) glanced through the handbook but could not apply it to his problem.” Moreover, the pupils in pair A hesitated to ask for help when faced with difficulties. It might be possible that they did not recognize the need for assistance as long as they were able to proceed by trial and error. Their need for help was not obvious from observing them.

In conclusion, the data indicate that pupils’ work was based on a problem-centered approach. The teacher confirmed this finding: “The most central aim in the learning environment was to develop students’ problem-solving skills by allowing the students to face technological problems with no ready-made recipe.”

Creative processes

There were many notes that indicated that the atmosphere was open, promoting creativity: “Atmosphere in the classroom is high and emancipated; the group easily reaches an agreement on the assignment of tasks; the pupils discuss and think aloud when programming, discussion is democratic; the pupils discuss the logical operations, listen to each others’ opinions (not underestimating others’ ideas).” The notes indicated that pupils trusted their team members and the power of teamwork; they thought positively and were motivated.

Almost no indications of the pupils' systematic planning (recognizing and finding facts related to the problem and setting goals and visions) or systematic activities to generate alternatives before the active construction phase were observed, even though planning tools and ideation techniques were introduced in the handbook. They seemed too eager to start the constructive work. It was seen in the notes and in the videos how the pupils began their work immediately after receiving the task assignments: "The pupils (pair B) began their work immediately after studying the problem. One pupil explored the programming environment while the other connected devices (a push-button and a motor) to the interface. Then they began their work by creating the program. A discussion then took place." However, an unplanned project quite often leads to ineffective work: "The work of pair (A) is of a trial-and-error type." On the other hand, the planning and pondering of various alternatives was observed at a later stage in the problem-solving process and the solutions of the groups were unique. All the programs had an analog temperature input and a loop structure. One third of the programs had an if-structure and half of them included a logical and. One group decided to utilize the trigger feature. It was concluded that the visual programming tool promoted individual, unique solutions. Two examples of team solutions were shown in Figure 1.

The debugging and evaluation of a program appeared to be easily accomplished by students with the blue ball icon that represented the movement of the program through the flow chart while it was running. The students could easily observe which of the commands was currently being processed. Moreover, it is easy to see how certain commands had an effect on devices such as a gate or a thermostat. The videos and notes revealed how the pupils continued to debug their program, modify parameters, add commands, and so forth: "A pupil (in pair B) starts to program, puts his finger on the screen, follows the blue ball, and looks at the fan. The fan does not rotate. The pupils discuss …" On the other hand, the pupils could not independently decide when the project was complete. The notes indicate that: "The pupils waited for the teacher's acceptance of their project." The researchers interpreted this to mean that pupils lacked the necessary tools and skills for evaluation.

Discussion

The Empirica Control system was developed to minimize the need for rote memorization of programming rules and to allow room for creative problem-solving activities. These goals were the focus of this study. From the data collected in this study it was clear that it is possible to organize control technology learning activities so that pupils can solve problems and simultaneously learn to autonomously construct computer programs for controlling processes. If the activities are carefully selected, they introduce pupils to the basic processes in control technology (cf. De Luca, 1992). In the teacher's opinion, one possible reason for the user friendliness of the Empirica Control program was the visual and schematic nature of programming. It was clear that creating programs in a graphic flow chart and allowing the program flow to be easily observed as it was executed are important.

Systematically teaching the programming skills to the students before they were presented with the problem may have been a more effective approach. Combining the learning of the programming approach with solving the actual problem resulted in a very complex process (Taylor, 1991). At times the pupils had difficulty proceeding with the solution of the problem, in spite of the teacher's indirect guidance. It seemed that if the students had become well acquainted with the Empirica handbook ahead of time, it would have ensured greater autonomy in solving the problem. This appeared to be especially the case with learners who had difficulty with independent learning. The videos clearly show pupils trying to glance through the handbook to find help in solving their problems. If they had studied the handbook first, it seems that they would have understood more about the structure of programs and consequently they would have been able to apply this knowledge to solving the problem with which they were confronted. Interestingly, it is possible that the high level of user-friendliness that the Empirica system provided might have actually promoted a trial and error approach instead of one that was more systematic. Since it seems to be difficult to integrate handbooks and other written materials in a problem-centered learning environment, the teacher might begin by combining open-ended problem solving and study of the handbook with short, easy problems. This could effectively introduce the concepts and the vocabulary while keeping a context of realistic practice. On the other hand, the teacher argued that directly teaching from the manual is contrary to the notion of student-directed learning.

The teacher succeeded very well in assuming the role of a tutor, giving pupils open-ended problems and asking questions to clarify the pupils' ideas. The pupils could also ask for help or ask the teacher questions. Nine times out of ten the teacher did not give direct answers but responded with additional "how" and "why" questions, or suggested the direction of thought the pupils might follow. It is challenging for the teacher to create an environment in which students can have sufficient time to learn new concepts well enough to apply them to the tasks at hand. The teacher described his work with: "The problem centered approach was very difficult for me, because I had to think hard all the time about how to avoid leading and how to ask indirect questions."

According to the field notes and videos, the pupils worked quite autonomously, but mainly "by trial and error." There was little evidence of reflective thinking. Systematic planning of the project or execution of plans was not observed. First-hand observations indicated that the lack of planning generated most of the difficulties experienced by pupils. All the difficulties pertained to programming. It is quite obvious that the pupils did not know programming well enough to apply it to the solution of the problem. The video showed how the teacher tried to introduce a stepwise analysis of the programs by analyzing the pupils' programs when tutoring, but pupils did not seem able to adopt this analytical method. Either the pupils did not understand the significance of such thinking or there was a breakdown in their communication with the teacher. Therefore, it was hypothesized that it is important to teach, either directly or otherwise, more about programming, at least in the beginning. For example, effective planning tools or strategies (e.g., utilizing the flow diagram or making a list of inputs, processes, and outputs) for the program design could be very useful in the design of complex programs (cf. Gustafson & Rowell, 1998, p. 160). The Empirica Control software is itself a planning tool, because it creates block diagram illustrations of programs and their progress when executed. On the other hand, linear strategies do not easily help pupils to generate several possible solutions to their problems (Welch, 1999). It would be interesting to investigate what effect the pupils' systematic planning has on their problem solving, although the teacher thought that such planning would be boring to the students.

The lack of guidance and the nature of the task assigned may explain the lack of ideation activities. The course did not include any instruction related to creative processes or methods. Therefore, pupils were most likely unaware of the basic principles of how to engage in creative work. In addition, the problems in the task assignments were typically very specific to technology rather than general in nature. In some cases, the problem was defined using technical words like "wiring" and "button" rather than words that may have been more easily understood. The task was approached in a technical way instead of as a functional problem. The pupils may not have seen the problems in the context of the technological world around them, and consequently could not start to solve them from their base of experience (cf. Runco & Okuda, 1988, pp. 211- 220). This was also the opinion of the teacher: " In the beginning of the technology course, special attention must be given to the technological world around us. The students have to be familiar with the examples of the feedback systems and loops etc. in real life situations." The problem solving experience lacked authenticity for the students. It was concluded that problems should be presented in authentic contexts and adequate time should be allocated at the beginning for the processing of ideas and the planning of solutions.

Overall, it appears that the pupils' work in this study was problem centered but it was not very creative. Indeed, creative processes were almost completely missing. In the approach used, students were not given the opportunity to formulate problems themselves even though such experiences are one of the most important phases in problem solving (Sapp, 1997, pp. 282-298). The approach did not encourage students to think of many possible solutions to the problems and then select the proper solution (cf. Amabile, 1996, pp. 88-89). Instead, they seemed to proceed with the first solution that surfaced and then apply it in a trial and error manner.

It seems that various ideation techniques (e.g., brainstorming and analogous thinking) need to be taught to students if they are to be successful in developing creative solutions to problem-centered projects (Smith, 1998, pp. 107-133). They must learn the facts connected to the background of the problem. This means that pupils have to collect relevant information about the problem and the processes that might be applied to its solution. Programming skills, even if they are working within a graphical environment like that used in this study, are needed if pupils are to realize their ideas. Pupils should also be familiar with creative ways of thinking such as how to think positively, give constructive criticism, ask relevant questions, and assist other pupils in developing their ideas. Various evaluation techniques must also be learned for each stage of the project.

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New Paradigm or Old Wine? The Status of Technology Education Practice in the United States

Mark Sanders

The notion that technology education is somehow quite different from industrial arts education has been around for half a century, when Warner and his graduate students first brought the study of technology to our field's attention.[1] DeVore (1964) drove the point home by arguing the case for technology as an "intellectual discipline," and many others have echoed this theme. Clark, (1989) suggested technology education represents a "new paradigm." *A Conceptual Framework for Technology Education* (Savage and Sterry, 1990) proposed a structure for a curriculum grounded in the processes of technology rather than the processes of industry, thereby consummating a divorce from industrial arts in the eyes of the profession. Most recently, the *Rationale and Structure for the Study of Technology* (International Technology Education Association, 1996) and *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association, 2000) underscore the premise that technology education is a new and different field of study.

Some have been less convinced that technology education represents a completely new "paradigm." Foster (1994b), for example, suggested "…technology education is simply the appropriate renaming of industrial arts" (p. 16) and concluded technology education might allow for the attainment of the unrealized ideals of industrial arts. Petrina and Volk (1995) echoed Foster's refrain, referring to technology education as old wine in a new bottle, "processed through the old winepresses of business, industry, and vocational education" (p. 33-34).

McCormick (1992), alluding to the continuing legacy of industrial arts, wrote: We must learn from various traditions because they encapsulate strongly held views and years of experience that will remain, even after we have an established area of technology education." All of this begs the question, To what

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[1] Although Warner's 1947 AIAA Conference presentation has commonly been cited as "A Curriculum to Reflect Technology," Latimer (1974, p. 71) found evidence that the 1947 paper was originally titled "The New Industrial Arts Curriculum." In 1959, Epsilon Pi Tau published a nearly identical paper titled "The Industrial Arts Curriculum: Development of a Program to Reflect American Technology." The term "technology" may have initially made its way into a revision of this paper as early as 1953. In 1965, Epsilon Pi Tau published a version of the paper titled "A Curriculum to Reflect Technology," with a subtitle that reads "AIAA Feature Presentation 15 April 1947," which is likely why it has generally been cited under this title with the 1947 publication date.

extent does current *practice* in technology education differ from that of industrial arts? While many have speculated regarding a "new paradigm," there has been a void of research upon which to make such claims. Petrina concluded, "…evidence is suggestive that relatively little time has been spent investigating the practice of technology at the local, school-based level." (1998, p. 35) Determining the extent to which the rhetoric of the profession has been translated into practice was an underlying purpose of this study.

Related Literature

Two comprehensive studies of technology education practice were conducted in the past half-century. Schmitt and Pelley (1966) conducted the first during the 1962-63 school year. They prefaced their report, *Industrial Arts Education: A Survey of Programs, Teachers, Students, and Curriculum*, with mention of the lack of previous research, "Heretofore, little factual information was available for curriculum specialists to use to improve this area of education." (p. iii). At least two of Schmitt and Pelley's conclusions remain timely and applicable today: 1) "… little attention has been given to developing in youth an understanding of technology and its impact on their lives;" and 2) "Industrial arts education draws upon the technology for its instructional content, and one of its main goals is directed toward developing technological literacy for all students in order for them to understand this new force—technology" (p. 2).

The Schmitt and Pelley study provided "benchmark data" referenced by the second comprehensive study of the profession, the "Standards for Industrial Arts Programs Project" (SfIAP Project), conducted nearly two decades later during the 1978-79 school year (Dugger, Miller, Bame, Pinder, Giles, Young, and Dixon, 1980). The SfIAP Project developed and distributed a 16-page survey instrument to a random sample of 1,404 industrial arts chairpersons, principals, and guidance counselors across the US. One general conclusion of this study was that relatively little change had occurred since the Schmitt and Pelley study 16 years earlier.

The methodology and findings from both of these earlier studies provided a context and comparative data for this study. All three studies taken together reveal a number of trends and common threads in the profession over the past four decades.

Several other related research efforts warrant mention. Beginning in 1985, a series of surveys were inserted into *School Shop* magazine (see Jones, Peckham, and Miller, 1985; and Dugger, et. al, 1986, 1990, 1991, and 1992). These surveys, distributed to about 45,000 subscribers (Bowden, 2000), focused on course enrollment data. While response rates were low—about 3% in 1985 decreasing steadily to 149 technology teacher respondents to the 1991 survey—their ranking of the top 10 course titles taught in the field (Table 3) was commonly cited in the literature of the field.

Scarborough (1989) surveyed selected technology education programs to determine the extent to which they had made the transition from industrial arts to technology education. But because she selected exemplary programs for her sample, this was more a study of “best practice” in the mid-1980s than a measure of the *status quo* of the profession.

Yu (1991) studied the emphasis placed on various program goals in Virginia. He spoke to the discrepancy between contemporary doctrine and practice in concluding “…technology education teachers still hold in high regard the goals of traditional industrial arts, while professional leaders/teacher educators favored contemporary technology-oriented programs” (p. 136).

Purpose of the Study

The purpose of this study was to begin to describe current programs and practice in technology education in the US and compare findings from this study with those of the two previous comprehensive studies of industrial arts education. This is an important undertaking at this particular time for several reasons. First, the field has been in transition from industrial arts to technology education for roughly two decades. In 1980, the first “Technology Education Symposium” was held, arguably signaling the turning point in the move to “technology education.” Moreover, the profession has recently adopted an expanded mission, building a case with *Technology for All Americans* for technology education for all students in grades K-12 (ITEA, 1996). This, and the more recent “*Standards for Technological Literacy* (ITEA, 2000) have drawn unprecedented attention to the field, prompting many to ask, “What is technology education?” While the aforementioned ITEA publications describe the current *ideals* of the profession, a measure of current *practice* is a better indicator of where the profession stands at this point in time. Finally, as the profession strives to accomplish new goals, it is helpful to make an honest assessment of how far the field has—or has not—come with respect to the ideals promoted throughout the profession over the past two decades.

With all of this in mind, three research questions framed this study:

1. What are the characteristics of current technology education programs and how do they compare to those of the industrial arts programs of the 1960s and 1970s?
2. What may be said of the current content taught and instructional methods employed in technology education?
3. What course titles are currently being used in technology education programs and what do these course titles suggest about the profession?

Method

Middle and high school technology education programs in the US served as the sampling frame for this study. Market Data Retrieval (MDR), the same company used to identify the sample for the SfIAP Project study conducted in 1978-79, was employed to assist in identifying the sample for this study. MDR’s educational database included 9,545 public high schools and 6,945 public middle schools in the US with technology education programs. Guidelines proposed by Krecjie and Morgan (1970) suggested that sample sizes of 370 high school and 364 middle school programs were sufficient to yield a 95% confidence level. Based upon an estimated 50% return rate, sample sizes were doubled to 740 high school and 728 middle school programs respectively. Systematic sampling (Nth selection), allowing a maximum of one teacher per school, was used to generate a random sample of 1,468 technology education teachers/programs for this study, similar in size to the sample of 1,404 used in the SfIAP Project in 1979.

In March 1999, a cover letter, survey instrument, and postage-paid return envelope were mailed to the random sample identified. Because "technology education" is often confused with, for example, computing education, a note of clarification in the cover letter and a statement at the top of the survey were used to direct the instrument to an industrial arts/technology education teacher rather than to computing or trades and industry teachers.[2] To encourage survey returns, each respondent was offered a chance to win one of three $100 gift certificates. Approximately 4 weeks after the first mailing, a second cover letter, survey instrument, and postage paid envelope were mailed to each non-respondent.

To address the issue of possible non-response bias, the survey was mailed a third time to a random sample of 25 non-respondents. Follow-up phone calls were made to those individuals to encourage response, or to administer the survey via telephone. Additional follow-up phone calls were made until 100% response of these previous non-respondents was achieved.

Instrumentation

The development of the "Technology Education Programs Survey" (TEPS) instrument used in this study began with a careful review of the instruments used in the Schmitt and Pelley (1963) study, the SfIAP Project (1979) study, and the *School Shop/Tech Directions* studies of 1986, 1989, 1990, and 1991 (Sanders, 1999a). Throughout the development of the TEPS, a panel consisting of three technology teachers, seven technology education graduate students, four technology teacher educators, two educational research faculty, and a research specialist reviewed the instrument and provided revision suggestions. With their input, numerous revisions were made to the instrument throughout the development process.

To facilitate a comparison of current practice with industrial arts programs of the 1960s and 1970s, 30 items were developed for the TEPS instrument that paralleled those used in the SfIAP Project (Table 1), many of which were also used in the Schmitt and Pelley study.

[2] The note at the top of the survey instrument outlined with a border, read, "This survey is intended only for those who teach or supervise Technology Education/Industrial Arts (TE/IA). If you do not, please give this survey to the TE/IA Chairperson in your school. If no such teacher, please return it in the postage-paid envelope. Thanks!"

Table 1
Survey Questions Nearly Identical to Those Used by the SfIAP Project (1979)

Technology Education Programs Survey[1] (1999)		SfIAP Project[2] (1979)
Ques #	Approximate Wording of theTEPS Instrument Items Used in this Study	Ques #
3	With which of the following programs is your TE/IA program most closely associated? (Gen Ed ,Voc Tech Ed)	1
4	What is the average number of years faculty in your program have taught TE/IA (in any school)?	27
12	Over the past five years, funding for your TE/IA Program has…? (Decreased, Remained the Same, Increased)	17 & 18
17	What % of your TE/IA faculty are certified or licensed to teach TE/IA?	28
18	What % of your TE/IA faculty are members of the International Technology Education Association?	25
20	About what % of students in your TE/IA program are female?	5
21	About what % of students in your TE/IA program are minority (non-Caucasian) students?	23
22	About what % of students in your program are "gifted and talented" students?	21
23	About what % of students in your program are "special needs" students?	21
31	Does your TE/IA program have a student club (and if so, is it TECA affiliated)?	31
32	Do you have an Advisory Committee specifically for your TE/IA Program?	29
34	What one selection below best describes your TE/IA facilities? (Unit Lab, Systems Lab, General Lab, Modular Lab)	7
38	The most significant barrier to an outstanding TE/IA Program is____?	2
45-60	Rate the following purposes of TE/IA… (Develop problem-solving skills; Develop worthy leisure-time interests; Develop an understanding of the nature and characteristics of technology; and 13 other purpose statements)	4
Part Two	List the courses taught in your TE/IA Program (as well as grade levels, enrollments, % females enrolled, and # of sections)	5

[1]Sanders (1999b); [2]Dugger, et al. (1980)

Items #45-60 on the TEPS asked respondents to rate 16 purposes of technology education/industrial arts (Table 2). Ten of those 16 choices appeared on the Schmitt and Pelley study and 12 appeared on the SfIAP Project instrument. Four new purposes were paraphrased from the "Program Goals for Technology Education" presented in *A Conceptual Framework for Technology Education* (Savage and Sterry, 1990) and added to this section of the TEPS instrument. Thirty additional questions were developed in accordance with the three research questions guiding the study.

Results and Discussion

The two mailings of the instrument to the 1,468 teachers resulted in 418 returned surveys. Of these, 406 (27.7%) were useable. Responses from the third follow-up study of 25 initial non-respondents were consistent with those of the earlier respondents. However, six (24%) of the 25 schools that had been randomly selected from the pool of initial non-respondents, did not have a technology education program. Breakwell, Hammond, and Fife-Schaw (1995) suggested that researchers calculate and report response rate based upon the "achievable base," rather than the actual base. If one assumed the achievable base of technology teachers was 24% smaller than the number originally indicated by Market Data Retrieval, the adjusted response rate would be 36.4%.

Research Question #1: What are the characteristics of current technology education programs and how do they compare to those of the industrial arts programs of the 1960s and 1970s?

Program Name and Philosophy

What's in a name? Nearly six out of ten respondents (58.6%) call their programs "technology education;" while about one in ten still use "industrial arts" (Figure 1). Another 20.2% hover in the middle with "industrial technology."

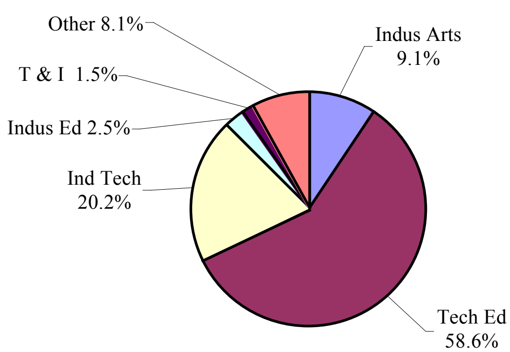

Figure 1. Program name (what respondents call their programs).

More than half (60.3%) associated their programs most closely with "general education"[3] very similar to the percentage reported two decades earlier in the SfIAP Project study (54%). Despite efforts throughout this century to place technology education in the general education arena (see, for example,

[3] In order to maintain consistency with the earlier SfIAP Project study, four options were provided for this question: General Education (55.2%), Preparation for a College Education (5.1%), Preparation for Vocational/Technical Education (23.4%), and Vocational/Technical Education (16.3%). For reporting purposes, the first two categories were combined into "General Education" and the latter two were combined into "Vocational Education."

Bonser and Mossman, 1923; Wilbur and Pendered, 1973) and the current "technology for all Americans" mantra, four programs in ten (39.7%) of the TEPS respondents felt their program was most closely associated with "vocational education," as had 36% in 1979. This might be because many technology education programs are still *administered* under "vocational education" administrative structures at the local and state levels.

Faculty Demographics and Professional Activity

The average number of faculty in programs surveyed was 2.5, a slight decline from the 2.8 average found by the SfIAP Project in 1979. While the shortage of women throughout the profession remains one of the most pressing problems confronting our field, there are about ten times more women teaching technology education today (10.1%) than the 1% reported by the SfIAP Project twenty years ago (Figure 2). Nonetheless, technology education faculties are still overwhelmingly comprised of white (94.1%) men (89.9%).

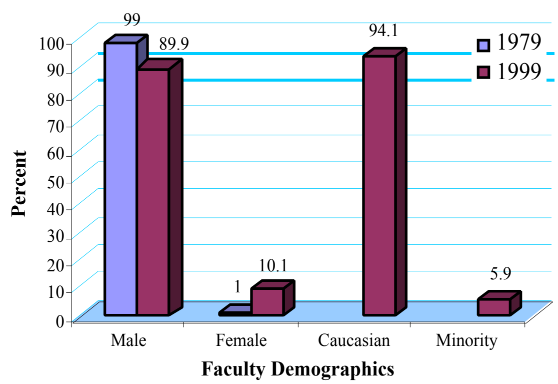

Figure 2. Comparison of faculty demographics between 1979 and 1999.

As many have surmised in recent years, the technology teaching workforce is aging. Technology faculty now average nearly twice as many years of experience (17.5) as reported by Schmitt and Pelley in 1963 (Figure 3).

Figure 3. Comparison of faculty experience over the past four decades.

Technology education programs were more than twice as likely to have faculty with 25 years of teaching experience (24.7%) than with 6 or fewer years of experience (11.8%).

Faculty were about ten times more likely be in their 40s than in their 20s (Figure 4). That said, only 7.4% of the faculty were reported as being over 55. The field may more likely be ready for a mid-life crisis than a retirement party.

1979, 16.8% of those enrolled in the 10 most-taught industrial arts classes were female (the overall percentage of female enrollment was not reported by the SfIAP Project). Though a very substantial gender-gap remains, technology education has made progress in this regard. The data suggest that one third (33.3%) of those now enrolled in technology education are female. Moreover, nearly half (46.2%) of middle school technology education students are female (Figure 5). Similarly, females accounted for 43.5% of the enrollment in 318 middle school level general technology education courses listed in Part II of the TEPS. As shown in Figure 5, female enrollments drop off radically at the high school level.

Figure 6. The percentage of students served in 1979 and 1999.

About one fourth (26.2%) of those enrolled in technology education are from minority populations, nearly identical to the percentage of minority persons in the general US population (Westphal, 1999). This is up from the 18% reported in 1979, reflecting the general growth of minority populations in the US over the past two decades (Figure 7).

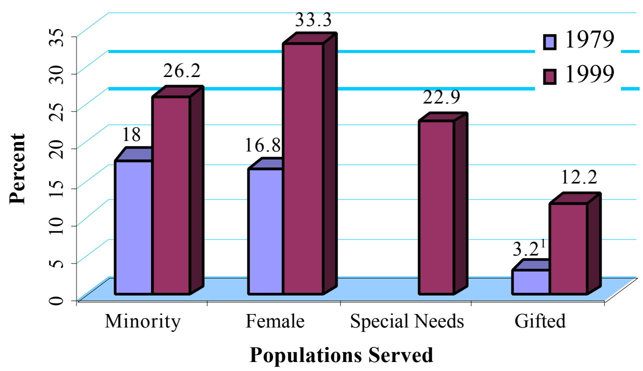

Figure 7. *Comparison of enrollment demographics between 1979 and 1999.*

Respondents indicated that 22.9% of those enrolled in their technology education courses were "special needs" students. It should be noted here that the phrase "special needs" was open for interpretation, and respondents may not have been fully qualified to answer this question—providing, instead, an educated guess. For purposes of comparison, the US Department of Education (1999) identified 11% of 6-21 year olds in the US as having "disabilities," though the terms "disabilities" and "special needs" have different meanings. At the other end of the spectrum, TEPS respondents identified 12.2% of their students as "gifted and talented." In contrast, guidance counselors surveyed by the SfIAP Project reported only about 3.2% of industrial arts students to be "above average" and only about .5% as "well above average."

Student Organizations and Advisory Committees

Participation in student organizations is on the rise. About twice as many programs reported having technology education student organizations (26.4%) than the 14% reported in both the 1963 and 1979 studies (See Figure 8). But fewer than one in ten (8.1%) were affiliated with the Technology Student Association (up slightly from the 5% affiliated with the American Industrial Arts Student Association (AIASA) in 1963 and the 4.6% reported in 1979). About one fourth of the technology education programs surveyed (23.4%) had an advisory committee.

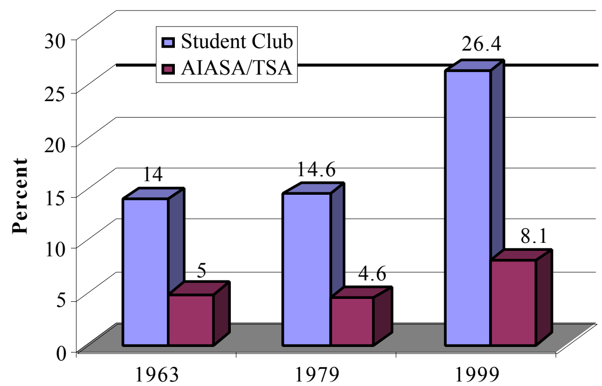

Figure 8. Comparison of participation in student clubs/associations over the past four decades.

The Purposes of Technology Education

Respondents were asked to rate the importance of 16 different "purposes" of technology education on a scale from 1 to 10. Ten of these had appeared in the Schmitt and Pelley study (1963) and a dozen were included in the SfIAP Project (1979) study. Four new purposes were paraphrased from the "Program Goals for Technology Education" presented in *A Conceptual Framework for Technology Education* (Savage and Sterry, 1990, p. 20) and added to this study. Table 2 shows a rank-order comparison of the purposes of technology education as reported in this study, the SfIAP Project data collected in 1979, and the Schmitt and Pelley Study of 1963.

There has been a noticeable shift in the perceived purposes of the field, from tool skills (industrial arts) to problem-solving (technology education). Each of the two earlier studies ranked "Develop skill in using tools and machines" as the number one purpose of industrial arts. But this purpose plummeted to the 11th of 16 options in this study. Similarly, "Provide technical knowledge and skill" dropped from second in 1979 to sixth in this study. At the same time, "Developing problem-solving skills," and "Use technology (knowledge, resources, and processes) to solve problems and satisfy human wants and needs" were ranked as the number one and two purposes respectively in this study. The latter didn't appear on either of the earlier studies, but was suggested in *A Conceptual Framework for Technology Education* (Savage and Sterry, 1990, p. 20). Problem-solving was of moderate importance in industrial arts, ranking fifth in both the 1964 and 1979 studies.

The application of science and mathematics was essentially ignored in industrial arts education, ranking last in both 1963 and 1979, but ranked fourth (of 16 purposes) in this study. In practice, however, coordinating technology education with mathematics and science teachers is still relatively rare.

Table 2
Purposes of Technology Education Compared

Purposes of Technology Education	Mean	Rank	1979 Rank[1]	1963 Rank[2]
Develop problem-solving skills [1,2]	8.94	1	5	5
Use technology (knowledge, resources, and processes) to solve problems and satisfy needs and wants [3]	8.57	2	NA	NA
Make informed educational and occupational choices [1]	8.28	3	7	NA
Understand the application of science and mathematics [1,2]	7.97	4	12	10
Develop an understanding of the nature and characteristics of technology [1]	7.85	5	11	NA
Provide technical knowledge and skill [1,2]	7.75	6	2	4
Recognize that problems and opportunities relate to and often can be addressed by technology [3]	7.63	7	NA	NA
Discover and develop creative talent [1,2]	7.46	8	3	2
Identify, select, and use resources to create technology [3]	7.34	9	NA	NA
Provide pre-vocational experiences [1,2]	7.22	10	9	6
Develop skill in using tools and machines [1,2]	7.14	11	1	1
Develop consumer knowledge and appreciation [1,2]	6.68	12	8	9
Evaluate the positive and negative consequences of technological ventures [3]	6.64	13	NA	NA
Understand technical culture [1,2]	6.61	14	6	7
Develop worthy leisure time interests [1,2]	5.73	15	4	3
Provide vocational training [1,2]	5.55	16	10	8

[1] From the SfIAP Project study; [2] From the Schmitt and Pelley study; [3] Paraphrased from *A Conceptual Framework for Technology Education* (Savage and Sterry, 1990)

Respondents indicated that only 13.3% of instruction, on average, was “interdisciplinary with math and/or science teachers.”

The field is losing interest in the goal of helping students develop leisure time interests. This purpose ranked third in 1963 and fourth in 1979, but dropped to 15th (of 16) in this study.

Although Savage and Sterry (1990, p. 20) identified the “evaluation of the positive and negative consequences of technological ventures” as an important goal of technology education, it ranked very low (13th) in this study. In other words, practitioners perceive this to be a much less important purpose than did technology education leaders.

Recent Support for Technology Education

A series of questions asked about enrollment, staffing, and funding trends over the previous five years. Over that span, enrollments and class sizes in technology education programs were generally stable or on the rise (Figure 9) and were roughly parallel to the overall school enrollment figures reported. Concurrently, funding support was reported to be either stable (48.1%) or in decline (30.2%) and the number of faculty, on whole, remained relatively stable.

That is, technology education programs were just as likely to have increased their number of faculty (17.9%) over those five years as they were to have decreased in size (17.9%). The relatively level funding and faculty numbers, juxtaposed with increasing enrollments, class size, and inflation during this five-year span, suggests a net loss in "buying power" in recent years. Not surprisingly, the most significant barrier to having an outstanding program reported was lack of financial support.

The pros and cons of “modular technology education” have been a recurring source of analysis and debate (see, for example, Petrina, 1993; Foster, 1994a; Brusic and LaPorte, 2001). Just how prevalent is the modular approach? Respondents were asked which of the following best described their facilities: “Unit Labs (e.g., Woods, Electronics, Drafting); Systems Labs (e.g. Production, Communication, Transportation); General Labs (wide mix of equipment in each lab); or Modular Labs (e.g., Synergistics, etc.).” While about one-sixth described their facilities as modular, the unit and general laboratories popular throughout the past century are still more prevalent than modular laboratories (Figure 10).

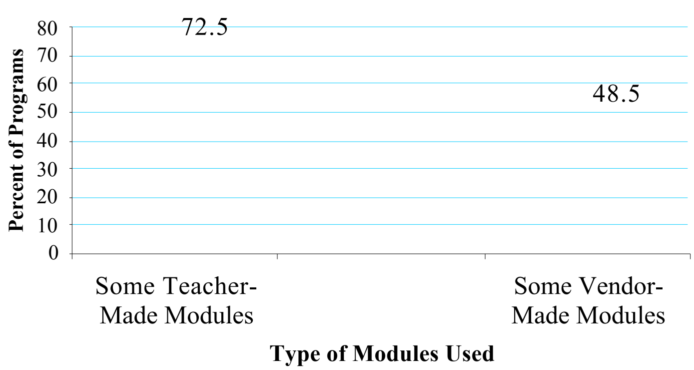

Figure 11. Teacher-made and vendor-made modules used in programs.

It appears there is no one dominant instructional approach to technology education. Respondents were asked to identify the "teaching approach most used" in their programs. As Figure 12 indicates, there was a fairly even split among the modular approach (35.4%; divided between "vendor-created" and "teacher-created"), the project approach (27.9%; "projects from plans provided by instructors"), and a design and technology approach (36.7%; "students design and build solutions to problems posed by instructors"). Looking at it another way, nearly three-fourths of instruction does *not* utilize the project (from plans) method that was popular during the industrial arts era.

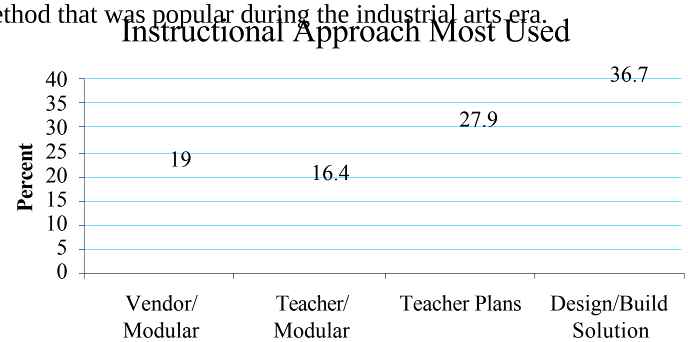

Figure 12. Respondents were asked to select the "most used instructional approach" from these four options.

Instructional Content

The *Conceptual Framework for Technology Education* (Savage and Sterry, 1990, p. 14), widely distributed by the ITEA, promoted four major "technological processes" (commonly referred to in the field as "content "organizers"): communication, production, transportation, and bio-related technology processes. A series of questions on Part I of the TEPS asked respondents the percentage of their total instructional content represented by each of these four organizers. Production and communication make up the majority of the curriculum (Figure 13). Transportation is more modestly represented, while bio-related technological processes remain almost non-existent in the curriculum.

Figure 13. Respondents were asked to divide the content taught in their program into these five categories (such that their total equaled 100%).

Research Question #3: What courses are currently being used in technology education programs and what do these course titles suggest about the profession?

Part two of the TEPS asked respondents to list all courses taught in their programs, along with course duration and enrollment data. This resulted in a list of 1,756 courses. Because of the plethora of specific course titles, and in an attempt to compare current course title trends with the Schmitt and Pelley data of 1963 and the SfIAP Project data of 1979, course titles were grouped into categories with names similar to those used in the earlier studies. These, and some newly identified course categories appear in Tables 3 and 4.

As shown in Table 3, surprisingly little change has occurred in the ranking of the top ten course categories taught over the past four decades. Because of large middle school enrollments, the “General Technology Education” course category was the most often taught category in 1999, as was “General Industrial Arts” in 1963 when Schmitt and Pelley surveyed the profession. If “Architectural Drawing/Architectural Drafting” (1999, Rank 5) is combined with “Drafting/CAD” (1999, Rank 2) as apparently had been done with “Architectural Drafting” and “Drafting” in 1963, and if “Graphic Communications” (1999, Rank 10) is combined with “Communications” (1999, Rank 8), the top six course categories in 1999 would be the same as the top six course categories taught in 1963.

Table 3
The 10 Most-Taught Course Categories in Technology Education/Industrial Arts

Rank	1999 [1]	1979 [2]	1963 [3]
1	General Tech Ed (429) [4]	General Woods	General IA
2	Drafting/CAD (261)	General Metals	Woodworking
3	Wood Technology (180)	Mechanical Drawing	Drafting
4	Metal Technology (74)	Drafting	Metalworking
5	Arch Draw/Arch Draft (70)	General Industrial Arts	Graphic Arts
6	Electricity/Electronics (62)	Architectural Drafting	Electricity/Electronics
7	Manufacturing (57)	Graphic Arts	Crafts
8	Communications (53)	Auto Mechanics	Power Mechanics
9	Automotives (49)	Electricity	Home Mechanics
10	Graphic Comm (45)	Woodworking	Photography

[1] From this study; [2] From SfIAP Project; [3] From the Schmitt and Pelley study; [4] The number in ( ) indicates the number of courses conglomerated to create this category

Table 4 shows the “second ten” most-taught course categories. Course titles that included the “contemporary” nomenclature—Manufacturing, Communications, Construction, and Transportation—made their way into the “top 12” most-taught course categories in 1999. Interestingly, “bio” (as in “biotechnology” or “bio-related") appeared only four times, and "Design and Technology" appeared only once among the 1,756 titles listed.

Table 4
The 11th-20th Most-Taught Course Categories in Technology Education

Rank	Course Title
11	Construction (35)[1]
12	Transportation (35)
13	Materials and Processes (34)
14	Power (title implied automotive rather than energy) (24)
15	Welding (24)
16	Photography (21)
17	Modular Technology Education (20)
18	Computers (20)
19	Principles of Technology (19)
20	Architecture ["drawing/drafting" not used in title] (17)

[1] The number in ( ) indicates the number of courses in this category

Summary and Conclusions

Is current technology education *practice* in the US reflective of a "new paradigm" that Clark (1989) and others have proposed… or, is it more reminiscent of old wine in a new bottle, as Petrina and Volk (1995) concluded? This study provides evidence that substantive changes *have* taken place in technology education practice, particularly with respect to program names, the purposes of the field, students served, and instructional methods employed. But the magnitude of change pales in comparison with the shift from Ptolemy's view of the universe (with the earth at the center) to the Copernican view (with the sun at the center). The data suggest a decided, evolutionary shift—with the legacy of industrial arts still in evidence—rather than a total transformation of the field.

Programs calling themselves "technology education" now outnumber "industrial arts" programs six to one, with "industrial technology" claiming most of the middle ground. By and large, program names *have* changed. But names can be superficial. The more important question is, "How does the substance of technology education *practice* differ from that of the industrial arts era"?

One of the more telling shifts is in the perceived purposes of technology education. Practitioners report the teaching of problem-solving as the most important purpose of the field, supplanting the emphasis on skill development found in the two major previous studies. "Problem-solving" may be interpreted many different ways, so further research is necessary to clarify the nature of this particular shift. But the declining emphasis on tool skills sends a clear signal that technology education practitioners are thinking differently today than in decades past about the primary purposes of technology education.

Instructional method is another area of substantive change. Building projects from plans provided by instructors, an approach popular in the post

World War II era, is still the preferred approach in about one program in four. But "modular technology education" and "technological problem-solving," an approach in which students design and build solutions to problems posed by the teacher, are now more widespread than the project-from-plans method. That is, roughly three programs in four are using either the modular technology education or technological problem-solving approach to instruction, while one program in four prefers the project-from-plans method.

Significant demographic shifts have transformed the faculty and students of technology education, and the field is reaching a greater range and percentage of students than ever. While only one faculty in ten is female, this is ten times the percentage reported two decades ago. Similarly, one third of technology education students enrolled are female, about fifteen times the percentage of the early 1960s. Technology educators teach a high percentage of special needs students, and far more "gifted and talented" students, than did industrial arts programs in previous decades. Minority students comprise one fourth of technology education enrollments, paralleling the minority proportion in the general population.

Despite these demographic shifts, technology education is still taught mostly by middle-aged white men. The implications of an aging white male faculty at a time when the field is promoting "technology education for all" are obvious and *must not be overlooked*. Perhaps the good news is that increasing female and minority enrollments provide a larger pool from which to recruit future technology teachers. But since relatively few females take technology education courses beyond their middle school years, the field must find new ways to encourage female students to pursue technology education during high school, and technological careers—including technology education—thereafter. Similarly, the goal of "technology education for all" suggests a need for new strategies for recruiting minority populations into technology teacher education programs. As technology education continues to search for solutions to the growing teacher shortage, female and minority technology education students offer obvious and untapped potential.

For decades, the literature has encouraged new content for technology education, and the findings of this study suggest that communication, manufacturing, construction, and transportation technologies are increasingly represented in the curriculum. On the other hand, biotechnology clearly has *not* gained "market share" in the curriculum, despite ten years of encouragement from the profession. This forebodes the challenges that lie ahead as the field begins to address the new content areas stipulated in the *Standards for Technological Literacy* (ITEA, 2000).

There seems to be continued ambivalence regarding the relationship of technology education to vocational and general education. Despite efforts throughout the past century to distance technology education from vocational education, there is considerable evidence in this study of the sort of "border crossings" to which Lewis (1996) alluded. Four programs in ten still associate with vocational education, a slightly higher percentage than did so in 1979. This is probably because many technology education programs are currently administered and funded through departments of vocational education. Drafting/CAD—the most-taught high school technology education course category—is arguably vocational in nature, particularly when taught in the popular two- or three-course sequence. On the other hand, respondents ranked the two vocational purposes tenth and last in the list of 16 purposes for technology education. These waters are muddy; the absence of meaningful dialogue within the profession regarding the relationship between technology education and vocational education has led to continuing confusion both within and beyond the field. It is time the profession addressed this issue in an articulate and thoughtful manner.

As clichés go, neither old wine nor new paradigm seems to best describe current practice in technology education in the US. It's more like "something old, something new, something borrowed...." Considerable change has been taking place over the past few decades, but the legacy of industrial arts is also evident throughout the data. The dynamic between change and legacy seems to characterize the field at this point in time; technology education is a work-in-progress.

Acknowledgement

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Editorial

Teachers Researching, Children Designing

Gary Benenson

Why Research in Technology Education must Involve Teachers

The recent AAAS Research on Technology Education Conference (see Cajas, 2000) established both the need for research and some of the directions it should take. There was general consensus among the participants that research needs to focus on what actually happens in the classroom: how teachers teach and how students learn. Research should begin with some conception of the goals appropriate for technology education, and then look for the ways in which these are or are not achieved. Schoenfeld (1998), Lewis (1999), McCormick (2000) and Hennessy & McCormick (1994) also make the case for investigations grounded in classroom practice.

However, as so often happens in education, there is a wide gap between intention and implementation. Karen Zuga's paper (2000) showed that very little of the current research is focused on teaching and learning in technology classrooms. Moreover, participant Mark Sanders pointed out that the problem is compounded by a shrinking pool of researchers. Its importance notwithstanding, it is unclear who will actually do this research.

There is an obvious, but largely overlooked answer to this question. Even in the United States, teachers are gradually becoming attracted by the promise of technology education. Several large NSF-funded projects are demonstrating the potential role of technology as a spur to literacy, both as motivation for math and science, and for teaching general problem-solving strategies. The standards may also help in this regard. The *Benchmarks* (American Association for the Advancement of Science, 1993) clearly express the importance of technology in the curriculum while the national standards for mathematics, science, and English call for contextual learning that can easily occur within the contexts of technology. As teachers experiment with this new subject material, many issues about teaching and learning will naturally arise. With appropriate support, teachers can play key roles in exploring many of the research questions in technology education.

There is an even more important argument for teachers' participation in educational research. Too many educational research projects have little to do with the day-to-day realities of the classroom teacher. Teachers are sometimes seen as irrelevant to "larger issues" such as standards, curriculum, or children's cognitive development. This point of view is reflected in cynical terms such as "teacher-proof curriculum." At best, the traditional researcher regards the

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teacher as a “subject of study” rather than as a partner in the research effort. Partly as a result of these attitudes, few teachers think that educational research could be of much use in informing classroom practice. As Torbert (1981) pointed out, educational research that ignores the classroom is unlikely to have much meaning for classroom teachers.

Every classroom has its own accepted beliefs and norms, its own dynamic patterns of interactions, and its own authority structure. As in other primary groups, the individuals in a classroom develop shared perspectives that sometimes enable them to solve problems and negotiate differences (Charon, 1998). There are also larger social units that interact with the classroom; these include the school, the community and the school system. All classroom teaching and learning occur within complex social and cultural environments. Research that ignores these factors cannot provide much insight into how and what children learn in school.

Moving the research venue into the classroom is only a partial solution. Unless they have the time to live and breathe in the room for extended periods of time, researchers alone are unlikely to understand much of what is going on there. As Ball and Lampert point out, only an insider can be “aware of decisions we face ... rhythms of timing ... cues we read off students’ faces ...” (1998, p. 379). Furthermore, there are many research questions that only teachers really know about. These kinds of questions abound in the reflections of teachers about teaching. Examples from the areas of math, language arts, science, and art, respectively, are found in Schifter & Fosnot (1993), Gallas (1994), Doris (1991), and Cohen & Gainer (1995). Some examples from technology are presented later in this paper.

Teachers are generally not trained in research methods, nor are they likely to be experts in technology or other disciplines bearing on classroom practice, such as sociology, linguistics, or environmental psychology. The contributions of both teachers and researchers in the research effort are nicely summarized in the *Benchmarks* (1993, pp. 327-329). Research should draw on the widest possible range of knowledge and talent, both from inside and outside the classroom. “Partnership research” is a term that suggests the need for collaboration across disciplines and institutions, including K-12 schools and universities. However, as everyone knows who has tried, effective partnerships are easy to advocate but difficult to achieve. The next section explores some of the cultural barriers to collaboration, and suggests some ways to deal with them.

Understanding the Cultural Barriers

In the previous section, I argued that teachers and researchers need to collaborate, but is this really possible? Greeno, J. G., McDermott, R., Cole, K. A., Engle, R. A., Goldman, S., Knudsen, J., Lauman, B., Linde, C. (1999) discuss the often conflicting interests of three groups: teachers, researchers, and curriculum developers, but provide examples of collaborative work. At the end of the process, however, divisions still existed among these groups. As one teacher expressed it, “For the reform to make sense, we have to have more working with teachers and researchers, not two separate camps.” (p.330)

The existence of "camps" is a well-known feature of projects that involve both classroom teachers and university faculty. The daily experiences of these groups are very different, as are the power relationships, reward structures, and opportunities for professional recognition and growth. Sarason (1990, pp. 49-76) has written eloquently about the powerlessness of teachers and its consequences for educational reform. Ironically, the recent emphasis on standards has only made matters worse. Increasingly, K-12 classroom teachers are being robbed of professional dignity by overt and covert messages that say, "We don't trust you."

Compounding the internal problems of school systems are the complex and ambivalent relationships between schools and universities that Sarason includes in his description (1990, pp. 65-66). Many teachers are deeply mistrustful of university folk, whom they assume to be distant from the classroom and often in league with administrators. Professors who ignore this context are unlikely to establish successful collaborations with teachers. Asking a teacher for self-critical reflections, for example, can easily be misinterpreted as a ruse for finding evidence against her or him.

My own experience in doing professional development illustrates this ambivalent relationship. From 1992-1995, I was the Project Director of City Science Workshop, a professional development project located at the City College of New York. Its purpose was to develop strategies for using the urban environment in elementary science. During the first year of the project, we found it difficult to elicit reflections by the participating teachers. They were generally unwilling to evaluate their own work publicly. It now seems obvious that this reticence was one symptom of a larger problem of demoralization and mistrust. The demographics of the project staff and the participants were also factors: the three college professors leading the project were white men, while about 85% of the teachers were women of color.

The project staff discussed the problem of eliciting self-evaluation and came up with a plan. We decided that we needed to model the process of evaluation ourselves, so that the teachers would know what we were asking for. But, what should we evaluate? It would have to be an experience we had all shared. The only such experience was our own workshops. So, we decided that each of the three of us would prepare and present a brief evaluation of our own work in conducting the workshops. We would do these evaluations independently, without comparing notes.

At our next teacher workshop, we presented these evaluations as we had planned. Although each of the presentations was very different, all three were highly self-critical. We were probably more critical of ourselves than the teachers were of us. They paid very close attention. When the evaluations were over, there was a stunned silence among the teachers. Finally, one of the teachers broke the ice. She said, "Gee, you guys sound like real teachers!" Unwittingly, we had accomplished something more than modeling self-evaluation. By publicly offering reflections on our own practice, we had removed ourselves from the role of "experts" who had nothing to learn from the teachers. As a result of this session, the morale of the group began to improve noticeably.

A much bigger improvement came the following year, when we invited two of the teachers to join the project staff. They participated in all workshop-planning sessions and helped to lead the workshops. These teachers each had one foot in either “camp.” In helping to plan the workshops, they did more than bring their own perspectives and experiences. By their presence, they also challenged us to consider things from the teachers’ perspective and required us to speak in a language that was more accessible. They not only contributed valuable ideas and classroom experiences to the workshops; they also helped to make us better workshop leaders.

There is also a reverse side to the ambivalence that teachers feel towards professors. As I have already illustrated, teachers often believe that professors are too far removed from the classroom to be able to add much of value. At other times, teachers tend to think that we know more than we really do. An example of the latter occurred near the end of the City Science project. We held a final dinner for all of the teachers who had participated in the project. At this event, we distributed copies of some curriculum guides we had written, which described some of the topics we had explored. Looking through the guides, one of the teachers said, “Hey this is great! Why didn’t you give it to us before?” I responded, “We couldn’t have written this, except after working with all of you.” I was surprised that she hadn’t seen the role that she and the other teachers had played in *our* learning.

One more example of “culture shock” comes from our current project, City Technology Curriculum Guides, which is described in the next section. The project includes a Research Team from the Center for Children and Technology (CCT). Early in the project, I became concerned because I hadn’t seen the CCT staff recording some of the workshop activities. I asked Dorothy Bennett, the lead researcher from CCT, about this record keeping. She explained to me that the researchers were not the only people keeping records. In addition, the CCT staff had also been teaching the teachers to document the workshops, because the documentary record should be written partly from the viewpoint of the participants, not just that of the professional researchers. Also, documenting the workshops would help prepare the teachers to document their own classroom activities. This approach makes perfect sense, but it had completely escaped me!

The City Technology Project

The purpose of the City Technology Curriculum Guides is to produce materials for teachers to support the teaching of technology in the elementary grades. The project is based on the following basic ideas about technology and technology education:

- Technology is everywhere and includes all of the artifacts and most of the environments and systems experienced in daily life;
- Because it is so common, technology can be studied at little or no cost;
- This study includes both the analysis of existing technologies and the design of new ones.

Five teachers' guides have been produced in draft form and are currently undergoing field testing (refer to the reference list). A Professional Developers' guide will be produced during the year 2001.

The City Technology Curriculum Guides provide contexts as well as content and activities. Each guide begins with a chapter called "Appetizers" that suggests ways the teacher can get started in exploring the topic. The chapters that follow offer technical background information, stories from classrooms, activities developed by the teachers, literature links, and information on assessment, classroom management, and standards.

The guides were developed through a collaborative process, which included three different groups:

- Two college professors, one from the City College School of Education and the other from the School of Engineering;
- Two educational researchers from the Center for Children and Technology (CCT) of the Education Development Center (EDC);
- Thirty elementary educators, who work in the South Bronx, Harlem, and Washington Heights;

We began the project by recruiting 20 teachers to work with us as "Teacher Associates" and "Co-authors." We used these terms to emphasize that this was not the typical professional development project. The Teacher Associates would learn new ideas, to be sure. However, their primary tasks would be to modify and develop the ideas further, try them out in their own classrooms, and document the outcomes, for possible inclusion in the curriculum guides. The group included science specialists, an early childhood educator, a special education teacher, a language arts specialist, and regular classroom teachers from grades two through seven. In experience, they ranged from first-year teachers to some with more than 20 years in the classroom. Several teachers from the original cohort left the project during the first year. The recruitment process for the second year included interview sessions with Teacher Associates who were already in the program. The Teacher Associates who joined in the second year included a math specialist, a special education teacher, and an early childhood teacher.

During the first two years of the project, we developed curriculum ideas and pilot tested them in the classrooms of the Teacher Associates. We began each year with a summer workshop, which engaged the Teacher Associates in exploring each of the City Technology topics first as learners, and then as curriculum developers. In the initial sessions, the Teacher Associates engaged in "warm-up" activities designed by the project staff. These included "Map Your Desk," "Physical Controls Scavenger Hunt," "Decoding Bar Codes," "Make a Folding Box for a Toy Block," and "Explore the Inside of a Cylinder Lock." Each teacher subsequently selected one of the City Technology topics for further investigation. Working in groups, and with the support of project staff, the teachers elaborated upon their ideas, raised further questions, and developed their own investigations related to a topic. These explorations culminated in each group designing an activity for all of the Teacher Associates and Project Staff to do and reflect upon. At the conclusion of each summer workshop, the

Teacher Associates wrote down ideas for activities and curriculum units which could be pilot-tested in the Teacher Associates' own classrooms. Project staff collected all of these ideas into a "Big Idea Book", which became the basis for the pilot tests.

During each of the two academic years, the Teacher Associates pilot tested the ideas from the Big Idea Books as well as new ideas developed during the year. Project staff, including the research staff, met regularly with the Teacher Associates during the two academic years. These meetings included both hands-on activities, and opportunities for discussion and reflection on the pilot tests. The Teacher Associates kept portfolios of their classroom experiences, which later became the basis for the "Stories" and "Activities" chapters of the guides. Currently, the guides are being field-tested by teachers and professional developers in New York City, suburban Westchester and Putnam counties, Saginaw, Michigan and Las Vegas, Nevada. The next section describes the process of collaboration among the three groups in greater detail.

A Model for Partnership Research

Greeno, *et al* (1998) described a project in which there were three collaborating groups: teachers, curriculum developers, and education researchers. In the City Technology project, the lines were drawn somewhat differently. Our collaboration, like Greeno's, includes teachers and professional researchers. However, we describe ourselves, the two college professors, as "content specialists" rather than curriculum developers, because all three groups contributed significantly to the development of curriculum. The major roles and responsibilities of the three groups are described in the following paragraphs.

The Content Specialists included a mechanical engineering faculty member and a science educator. We provided overall direction to the project, proposed curriculum topics and themes, led the workshops, and did most of writing of the curriculum guides and all of the editing. In workshop planning sessions, we presented our initial ideas and then they would be modified considerably in discussions with the Research Staff, and sometimes with Teacher Associates who dropped in on these sessions. In the workshops, we wanted to provide starting points for what we thought could happen in the classroom. The workshop plans were never static. We often abandoned or modified our original plans to dwell on a topic in greater depth or respond to issues as they came up. The teachers made major revisions as well to the activities before implementing them in their classrooms. Some ideas were dropped altogether, others were modified, and still others were extended and developed in ways we could not have imagined.

The role of the Teacher Associates was to tailor the new curriculum ideas to their own situations, try them out with their students, and document the outcomes. The primary form of documentation took the form of portfolios, which included the following elements:

- Lesson worksheets describing the activities and units they had implemented, including materials used, teacher tips and strategies, and self-evaluations of the units;

- Samples of students' work, including writing, maps and drawings, and dialogue; and
- Teacher reflections, including preparation for the activities, tips and strategies, ideas for further extensions, and assessment techniques.

To capture additional information that did not appear in the portfolios, we held semi-annual Roundtable Portfolio Review sessions, where each teacher shared portfolio materials. After each presentation, the staff and Teacher Associates raised questions and comments in two categories. First, there were the "warm" comments, complimenting the presenter on aspects of the work, identifying ideas that could be used elsewhere, and suggesting larger significance for what had been done. Here are some examples of "warm comments":

- "There was excellent attention to children's language and ideas."
- "I especially like the way you made the City Technology topics into integrative year-long-themes."
- "You enable them to revisit the activity as they get new ideas."
- "It was wonderful that you had child-motivated extension activities."
- "You observe how kids naturally approach materials. Through open exploration, kids discovered that pumps have a function in a tangible way - e.g., when the kids used pumps to get water out of the water table. You give a real flavor for what a pre-K/K class is like."
- "It can be hard to see where children are taking an activity, especially when you don't expect it. I liked it when you said, 'I had them figured out all wrong.' "
- "You struggle to reach kids 'by any means' ".
- "You write down all of the kids' ideas."

These were followed by "cool" comments, requesting information that had been omitted, suggesting ways in which the work could be improved, and offering critical insights. Here are some examples of "cool" comments and questions:

- "What kinds of guiding questions did you have for them?"
- "What did they get out of it?"
- "What evidence do you have for their learning?"
- "How will the analysis lead to redesign?"
- "How did they collect and report data?"

The third group in the partnership was the Research Team. They developed a set of guidelines and worksheets for documenting classroom activities and units. These instruments were modified several times, based on comments and suggestions from the teachers. The researchers suggested the idea of having the Portfolio Roundtables, developed the format for them, and led these sessions. They conducted periodic interviews with the teachers about key issues identified from portfolios and journals, and provided advice to the Content Specialists regarding the appropriateness of various themes and activities. Perhaps most important, the Research Team attended all of the workshops and planning sessions, where they frequently raised critical questions both of the teachers and of the content specialists. While strongly supportive of the goals of the project, the researchers maintained an intellectual distance from the Content Specialists, making it easier for the teachers to challenge them as well.

The participation of the Research Team in the workshops, and the mechanism of the portfolio reviews, helped create an atmosphere of critical reflection that benefited everyone. It was possible to raise serious questions and criticisms without offending anyone or deepening the divisions between the three groups. This atmosphere of critical reflection also provided a model for teachers working with children. They were encouraged to listen more carefully to their children's ideas, to include these ideas in their portfolios, and to explore issues about children's learning. Although formal research was not a goal of the project, some teachers did collect valuable data about how children learn and understand technology. Some examples are reported in the next section.

Two Examples of Classroom Research

The most basic activity of technology is design, and the purpose of designing something is to address a human need. A fundamental goal of technology education, expressed most clearly in the *Standards for Technological Literacy*, is the understanding that "Everyone can design a solution to a problem" (ITEA, 2000, p. 93). Problems arise frequently that could be solved by a design or redesign, but few adults or children have learned to think of themselves as designers. One very powerful approach to redesign is outlined in the ITEA Content Standards: "All products and systems are subject to failure…. Troubleshooting helps people find what is wrong with the product or system so it can be fixed" (p. 107). Both of these standards are intended for children in grades K-2. To what extent and under what circumstances do young children actually learn these ideas about design?

Theresa Luongo is a pre-K/K teacher at a small alternative school in East Harlem. She has a large classroom with many distinct "areas" which afford many opportunities to explore and discover. Every day during "Work Time" Theresa allows her students to choose the area in which they want to work and the activities that interest them (Benenson, Neujahr, Bennett, Meade, Diez, Flores, Gatton, Gonzalez, Luongo, Odinga, Piggott, Purnell, Rivera, Skea, Smith, and Williams, 1999, p. 63-64). Theresa reported on how testing the strengths of shopping bags led to repair and redesign of bags and other objects (p. 67-71).

Theresa asked the students who chose the Block Area to see how many blocks some small shopping bags could hold. Eventually, the handle tore off of one of the bags. Two Pre-K students, a boy and a girl, offered to fix the broken bag, and this team was soon at work mending any bag that broke. Theresa extended this activity by asking these youngsters how a small paper lunch bag could be turned into a shopping bag. Repairing broken things and redesigning them so they won't break next time quickly became major activities in Theresa's classroom. After watching the repair and redesign of bags, another Pre-K student volunteered to repair book covers!

This story contains some powerful ideas about how troubleshooting, design, and redesign might become part of the everyday practice in early childhood classrooms. By encouraging children to explore the properties of a familiar artifact, the shopping bag, Theresa laid the basis for her students to experience technological failure firsthand. By providing opportunities for them to discover and explore for themselves, she implicitly motivated them to look for solutions when the bags failed. By posing the question, "How could I turn this lunch bag into a shopping bag?," she suggested a small-scale design problem related to the issues they were already exploring.

The design process is rarely a linear progression from problem to solution. Initial efforts at design are rarely the best, and children need to develop a willingness to revisit and re-do a design. This idea is expressed in the *Standards for Technological Literacy* in the following words: "It is important that students learn that applying the design process involves iteration. They should learn to use repetition and recurrence techniques to obtain the desired solution to a problem" (International Technology Education Association, 2000, p. 118). Unfortunately, the iterative problem solving notion runs counter to the prevailing paradigm in education that holds that an answer is either right or wrong, leaving little or no room for students to work their own way toward better solutions. The standard cited above is for grades 3-5. It would be very useful to know whether students in these grades actually accept the idea that design should be iterative, or if they see design in the more conventional terms of "right" and "wrong" answers.

Mary Flores is a Special Education teacher from a large school in the South Bronx. Mary works with small groups of children from grades three to five to develop basic literacy. She uses technology activities extensively in her classroom because they provide her students with many opportunities to discuss their ideas and express them in writing. Through multiple experiences in analysis and design, her students develop a strong sense of their own abilities to come up with solutions to problems. Mary wrote an account of how her students designed and redesigned "Rube Goldberg devices" as the culminating activity of an extended fourth and fifth grade unit on mechanisms. This unit had begun with brainstorming and scavenger hunts related to simple machines (Benenson, Neujahr, Bennett, Meade, Aguiar, Flores, Gonzalez, Monterroso-Nieves, Purnell, Rivera, and Williams, 1999, pp. 120-131).

In Mary's class, students recognized the need for iteration in design. One student built and tested a windlass made from a broomstick, a plastic crate, and a ruler. Then the student redesigned it using a cardboard box instead of a crate. One night the school custodian mistakenly discarded the mechanism the students had been working on. Mary was more upset than her students, one of whom stated, " Don't worry, Ms. Flores. We'll just do it again, and this time, we'll do it better!" Although her students accepted the need for iteration, they sometimes found it frustrating, as Mary discovered by interviewing her students. One girl remarked, " It's making me angry because I tried hard to make my mechanism work, but now I have to make another one." At the same time, several of her students were able to describe in detail the problems they encountered, and the steps they took to improve their designs.

Although neither Mary nor Theresa was engaged in a formal research project, both of their accounts provide valuable data for answering fundamental research questions. Both Mary and Theresa were pleasantly surprised by what happened in their classrooms. Theresa had not anticipated that bag testing would lead to the repair and redesign of bags, or to the repair of other items such as books. Mary had not expected her students to be so willing to evaluate and redesign their mechanisms. Nevertheless, these discoveries did not occur completely by accident. Both teachers see enormous potential for technology education in their classroom. Each in her own way, Mary and Theresa had laid the groundwork for what Eleanor Duckworth calls “the having of wonderful ideas.” As a result, they were both prepared to recognize the significance of their students’ work, and to document it in a way that could gain wider exposure.

Towards a Common Culture of Design and Research

The accounts in the previous section reflect not only the learning process of the children, but that of the teachers as well. Both Mary and Theresa listen to their students well and are sometimes surprised by what they hear. In the future they will approach these units with new understandings of how their students think about design and redesign. Both Mary and Theresa are very reflective teachers who try things out in the classroom, see what happens, and change what they do next time. They develop these classroom units in very much the same way that their children design things: they come up with an initial plan, try it out, and redesign it based on the outcome.

Near the beginning of this paper, I emphasized the cultural barriers that separate researchers and university professors from classroom teachers. As the City Technology project proceeded, these barriers began to disappear. There was a convergence of cultures, as it became clear that all of us were exploring uncharted territory, and that we needed one another’s help in doing so. “It’s another design project,” became the theme for all of the work that we were doing. While children were designing artifacts and classroom environments, teachers were designing classroom activities, the content specialists were designing professional development activities, and the research team was designing methods of data collection and analysis. Each of these designs was being tested by the other groups in the project, and subjected to analysis and criticism, and consequently being redesigned. This process of design-test-redesign occurred in the planning and implementation of the workshops, the design of curriculum by the teachers, the design projects undertaken by the children, and the design of research methods. Out of our separate cultures, a common design culture evolved.

There is considerable overlap between research and design, as is suggested by the frequent pairing of the words “Research” and “Development.” Research, at least in the applied sense, is usually a component of design. It is usually necessary to gather data about the problem to be solved, the materials that might be used, and the comparative worth of alternative solutions. Likewise, nearly every research project includes elements of design such as the design of the research plan, of the research methods and instruments, and of the means of presenting the results. Design and research have different purposes, but they share much of the same mind set. Because technology education is concerned with design, it is a relatively small step to apply design thinking to classroom research and development.

This paper suggests that teachers, content specialists, and researchers ought to collaborate in areas of common concern, such as classroom research and curriculum development. Many might argue against this notion. Doesn't each of these tasks require special training, which non-specialists are unlikely to have? Doesn't it blur the lines of responsibility to have everybody doing everything? Shouldn't everyone stick with what they do best?

Quite the contrary, there is a growing body of literature calling for collaboration in a variety of design professions. For example, in designing software for a Danish radio station, Bodker and Pederson (1991) realized that they had to first understand the culture of that particular workplace. Their discussion of the "insider-outsider dilemma" has close parallels with my own discussion of what insiders and outsiders can bring to classroom research. Similarly, Norman (1988) argued strongly for the "user-centered design" of consumer products. According to Norman, involving ordinary users in the design process is necessary, because no designer can anticipate all of the difficulties users will face in trying to make sense of the design.

In the area of engineering design, Pacey (1983) cited numerous examples in which new technologies failed, for reasons that were entirely non-technical. For example, more than 100,000 electric water pumps were introduced in India during the late '60's. By 1975, more than two thirds were not in use because there was no social system for maintaining them. The designers had focused on the technical aspects only, and ignored the social and cultural contexts of the users. Pacey's account raises an issue that is equally relevant to classroom research: how much weight should be given to user expertise, as compared with technical expertise? On a more hopeful note, Zeisel (1984) presented a variety of examples of successful collaborations between behavioral researchers and environmental design professionals. For example, in a chapter titled "Research and Design Cooperation," he described how behavioral research played a role in the design of an assisted-living facility for the elderly.

Collaboration between teachers and researchers, for the improvement of education, fits squarely in this movement towards collaboration in research and design. Technology education, furthermore, is the logical place to do it, because technology is about the analysis of problems in order to design solutions.

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Miscellany

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Errata

In the Fall 2000 issue (volume 12, number 1), the email address of Esa-Matti Jarvinen, a coauthor of the article titled “The Formation of Children’s Technological Concept: A Study of What It Means to Do Technology from a Child’s Perspective,” was incorrect. The correct email address is emjarvin@ktk.oulu.fi. Our apology goes to Esa-Matti for this error.