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From the Editor

Where Does the Sky End?

When I was a child, I used to lie on the warm grass of summer and gaze into the sky. Inevitably, my thoughts would lead me to wonder about where the sky ended. And if the sky ended, I wondered how thick the "wall" was that set the limits of the sky.

Some recent experiences have resulted in parallel thoughts about technology education. One was the Technology Education Research Conference, hosted by the American Association for the Advancement of Science last December. Fernando Cajas reports on some of the details of this conference in his editorial in this issue. During the conference, one of the moderators asked how many of the attendees considered themselves to be technology educators. All in the audience raised their hands in affirmation. Yet only about half of those present had formal degrees in the field. The others were cognitive scientists, science educators, mathematics educators, engineering educators, and others. All of these people were doing interesting and contributory work in technology education.

In May of this year I had the opportunity to visit Teknikens Hus (House of Technology) in Lulea, Sweden. In this facility, visitors can interact with a whole variety of technological systems. For example, youngsters (and adults!) can control the valves that direct water from a lake (on the second floor) to turbines that generate electricity. A full-size log loader was available (some functions disabled) with which participants could actually load logs onto a stack. A house built within the facility was modified so that all the essential systems could be readily seen. For example, the path of water running out of the kitchen faucet could be easily observed flowing through the transparent drain pipes within the walls and beneath the floor. Appliances were modified with transparent panels so that their operation could be understood. The directors of the facility clearly considered themselves to be technology educators, and rightfully so. A similar technology center is under development in Finland. An integral purpose of the Finnish center will be to serve and support technology education teachers. Though totally coincidental, it is timely that an article on science and technology centers by Richard Walton of the UK appears in this issue.

I recently learned about the implementation of technology education in Chile. Technology education is now required in that country for three hours a week for the first ten years of a child's education. The Ministry of Education is playing a significant role in the change to technology education. Unique, however, are the sponsors. They include an organization for interdisciplinary studies, an organization that provides training for construction workers, and an organization that facilitates the integration of advanced technology in business and industry. Even more remarkable are the expectations of these organizations. Universally, their purpose is to help assure that all their citizens become technologically literate as part of their general education. One Chilean engineer with whom I spoke talked about the importance of technology education with at least the same fervor that engineers from the US typically speak about the importance of science and mathematics.

Last spring, the *Standards for technological literacy: Content for the study of technology* was published by the International Technology Education Association through the Technology for All Americans Project (available on the Web at http://www.iteawww.org/TAA/STLstds.htm). This document and the work it represents will continue to receive attention as states and local schools use it as a guide in developing curriculum. In fact, the document is cited in three of the articles included in this issue. Like the other efforts mentioned above, this project represents a departure from the insularism that technology educators have tried to escape for years. It was funded by the National Science Foundation and the National Aeronautics and Space Administration. Support for technology education from agencies like these was unheard of just a few years ago (see the article by Custer, Loepp, and Martin herein). Involvement in the development of the standards was also quite broad, going far beyond the usual reaches of technology educators. Perhaps most significant was the involvement of the National Research Council and the National Academy of Engineering. Writing on behalf of those groups, William Wulf pointed out that the Standards are intended to address the needs of all those concerned about technological literacy, not just the “professional interests of technology educators” (Wulf, 2000, p. 12).

The expanding horizon of technology education will present challenges to all involved. In meeting these challenges, each constituent group could stake out their territory and put up their fences, evangelizing that they have the way, the truth, and the light in how to develop technological literacy. Clearly, the more viable approach is to recognize the diversity of all the participants and use it to best advantage in the overall effort. Just as we recognize that there is no single best solution to a technological problem, there is no single best solution to developing the technological literacy of our citizens. All of us concerned about students and technology need to figure out how we can work together for our common purpose. If we can achieve this, it would set a landmark example for the rest of the educational community, tying together formal and informal education across a wide range of academic disciplines.

My experiences over the past year have caused me to realize that technology education is much greater than I ever imagined. The opportunities abound and the sky is the limit. The sky is the limit… Hmm… I feel the warm grass of summer against my back once again…

JEL

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Articles

Some Factors Predicting the Adoption of Technology Education in New Mexico Public Schools

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In 1984, delegates of the American Industrial Arts Association (AIAA) changed its name to the International Technology Education Association (ITEA) (Godla, 1988). Along with the name change, industrial arts, with its focus on industry, was expected to change and encompass a broader point of view involving total systems. Four technological systems were identified: manufacturing, transportation, communication and construction (G. M. Rogers, 1989; Snyder & Hales, 1981).

New Mexico began its transition from industrial arts to technology education in the late 1980s. With this came a change in focus from learning "hands-on" skills to understanding technological systems and their impact on society. The transition has been a slow one to date. Therefore, research was needed to gain a better understanding of the factors that are related to the adoption of technology education in New Mexico public schools. The outcome of such research would help educators and change agents to successfully integrate technology education into the curriculum.

Review of Literature

Technology education seeks to reach all students, not only those choosing to go into a technical field as a career. The processes of problem solving and critical thinking using technology, and understanding the social impacts of technologies, are very important in today's ever-changing world. The promise of the future lies not in technology alone, but in people's ability to use, manage, and understand technology (Dugger & Satchwell, 1996).

Technology education is emerging as an essential part of general education for all students. It can be offered at each grade level, starting with technology awareness in the primary and elementary grades and advancing to more specialized study at the high school level in areas such as computer aided drafting (CAD) and computer programming (Sharpe, 1996). This is in contrast to industrial arts, which was primarily taught in the upper grade levels (grades 9

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to 12). Philosophically, teachers in technology education assert that all ages can and should learn to utilize technology to solve problems and change the environment around them, leading to an enhanced quality of life.

The Jackson Mill Curriculum Project (Snyder & Hales, 1981) recognized the technologies of communications, construction, manufacturing, and transporta-tion as basic to human endeavor and suggested them as the content organizers for what in the 1980's was predominantly industrial arts. Ten years later Savage and Sterry (1990) led a team that proposed a conceptual model for technology education comprised of communications technology, physical (production and transportation) technology, and bio-related technology. Students were to be taught by applying an input-process-output model that addressed human needs and wants through the identification of problems and opportunities. The conceptual model stated that every area of the curriculum can be enriched with technology and that all students will be able to enhance their educational experience with the skills and understanding received in technology education.

The emerging discipline that is now technology education has changed through the years. In some instances existing programs were simply relabeled, starting with manual training and progressing through manual arts, industrial arts, and industrial technology education (Clark, 1989). In many cases, the old tools of industrial arts programs have simply been replaced with the new tools of technology education (Wicklein, 1997). For example, computer aided drafting replaced the drawing board.

Though industrial arts was considered an element of vocational education in some states, technology education is intended to play a major role in the future of education as a primary subject in the school curriculum (D'Apolito, 1997). Wright and Barella (1981) felt that many industrial arts teachers remain comfortable with their established program and are not making an effort to change to technology education. They recommended that each industrial arts educator develop a clear understanding of where the field has been, why it was the way it was, and how it has changed. This would enable the teachers to develop reasoned paths into the future.

Research results support the perception that technology education has not been met with widespread teacher acceptance. A study in Nebraska by Rogers and Mahler (1994) indicated that the majority (77.5%) of industrial technology education teachers did not accept the new technology education curriculum. In a much earlier study, Swanson (1981) found that the majority (68.8%) did not adopt the notion of technology education.

On the other hand, it is clear that leaders in the field feel that technology education is an innovation that needs to be diffused into the current educational setting. E. M. Rogers (1995) defined diffusion as the process by which an innovation is communicated over time among the members of a social system through certain channels. Diffusion theory is based on research that has been conducted for many years and in many disciplines. Gabriel Tarde first observed the diffusion of innovations within society in 1903 and referred to it as "the laws of imitation" (in E. M. Rogers, 1995, p. 40). Since the time Tarde made his observations, diffusion research has been conducted in such diverse fields as anthropology, sociology, education, public health, medical sociology, communication, marketing, and geography (E. M. Rogers, 1995).

In order for technology education to be diffused, the factors that influence the adoption process need to be identified. These factors will provide information about what can be done to increase the rate of adoption. E. M. Rogers (1995, p. 208) provided such a theoretical framework.

First, E. M. Rogers proposed that innovations that possess certain attributes are more likely to be adopted. These attributes are relative advantage, compatibility, complexity, trialability, and observability. The relative advantage of technology education is the degree to which it is perceived by teachers as being better than industrial arts. The compatibility of technology education is the degree to which it is perceived as being consistent with the existing values, past experiences and needs of teachers. Complexity is the degree to which technology education is perceived by teachers as difficult to understand and use. Trialability is the degree to which technology education may be experimented with on a limited basis before teachers make a decision to adopt. Another attribute to consider is observability, the degree to which the results of an innovation are visible to others. Many educators are hesitant to change an existing program to something they only know through discussion and reading and not through observation.

Second, E. M. Rogers proposed that adoption of an innovation is related to innovation-decision process. This is the process through which an individual (or other decision-making unit) passes from first knowledge of an innovation, to forming an attitude toward the innovation, deciding to adopt or reject the innovation, implementing the new idea, and confirming the innovation decision. Rogers stated there are three possible types of decisions that can be made regarding the innovation. First is the *optional* decision in which the adopting individual has almost complete responsibility for the decision. Second, is the *collective* decision in which a group makes the decision but the individual has some influence in the process. Third is the *authority* decision in which the adopting individual has no influence in the innovation decision because the decision is made for the individual by others.

E. M. Rogers (1995) indicated that the fastest rates of adoption for innovations usually result from authority decisions. G. E. Rogers (1989) explained that technology education was externally developed, creating animosity among the teachers who were to implement the idea internally. As is true with the majority of professional associations in content areas, the majority of industrial arts teachers were not members of the ITEA. Due to the lack of involvement in a professional association, these teachers did not have a full knowledge of the changes occurring in the field. Thus, the majority of teachers were not predisposed to the idea of technology education. These non-members then became the majority of teachers who were asked to implement the new technology education programs (G. E. Rogers, 1989).

Third, E. M. Rogers (1995, p. 208) proposed that the channels used to communicate the innovation and the social system in which diffusion takes place are factors that determine the rate of adoption of an innovation. Because of the difficulty in quantifying these variables, only the perceptions of the influence of opinion leaders (i.e., peers) on adoption was measured in this study. Opinion leaders may have influenced initial reaction to the name change of industrial arts to technology education. Peer-to-peer communication at the persuasion stage of the innovation-decision process is usually integral to innovation decisions. E. M. Rogers (1995) stated that when the norms of the social system are opposed to change, then the behavior of the opinion leaders correspondingly reflects these norms.

The extent of the change agents' promotional efforts is another factor that determines the rate of adoption of an innovation (E. M. Rogers, 1995, p. 208). Linnell (1992) stated that facilitators of change must provide support and follow-up activities for an adequate period of time to confirm adoption. Rogers and Mahler (1994) concluded that leaders in the field of technology education must interact with industrial arts teachers through various diffusion activities; the practice of promoting the change to technology education through top-down communication must be discontinued.

Change agencies (e.g., state departments of education, university engineering and teacher education programs, two-year post secondary institutions, school districts, and industries) could provide staff development and in-service training for teachers involved transitioning to technology education. Weissglass (1991) suggested that providing information is not sufficient to overcome the obstacles to change caused by the culture of schools and the teachers' lack of awareness of the need for change. He also indicated the following steps should be taken by change agents relative to those teachers who were being encouraged to change: breakdown their isolation; improve their listening skills; provide opportunities for them to express their feelings about the change; address their personal concerns; and establish support networks for them.

According to Nee (1993) traditional industrial arts teachers have not connected to technology education because of high complexity, low compatibility and problems with change agents. Also, these teachers are unwilling to try the new program due to the lack of stable support offered from their administration.

Purpose and Objectives of the Study

The purpose of this study was to determine which factors might predict the adoption of technology education by secondary technology education and industrial arts teachers in New Mexico. The subordinate objectives of the study were:

1. To describe technology education and industrial arts teachers by gender, age, teaching endorsements held, program budget, grade level taught, and years of teaching.
2. To describe technology education and industrial arts teachers by their perceptions of the attributes of technology education; perceptions of how often optional, collective and authority program decisions are made; and

influence of change agents and opinion leaders on adoption (E. M. Rogers, 1995).

3. To describe technology education and industrial arts teachers by level of adoption of technology education.

Method

A list of 310 secondary technology education and industrial arts teachers in New Mexico, provided by the New Mexico State Department of Education, served as the frame for the study. It was determined that a sample size of 169 was needed to represent the population at a confidence level of 95% (Krejcie & Morgan, 1970). A sample of this size was then randomly drawn using a table of random numbers. The study used a multivariate correlational design to determine the factors that predict the adoption of technology education by secondary industrial arts and technology education teachers in New Mexico.

A mailed questionnaire was designed by the researchers to measure the variables of the study based upon the work of E. M. Rogers (1995). The questionnaire contained summated indices made up of Likert-type questions to determine the level of adoption of technology education (18 items), perceptions of the attributes of technology education (10 items), and the influence of change agents and opinion leaders on adoption (8 items). Perceptions of how often optional, collective, and authority program decisions are made were each measured with a single Likert-type question. The remaining portion of the questionnaire consisted of demographic questions on gender, age, teaching endorsements held, program budget, grade level taught, and years of teaching. The questionnaire also contained three checklists to provide a second analysis for the main objective of the study. These checklists measured the three most important things that were helping teachers adopt technology education (promoters of adoption), the three most important things that were preventing teachers from adopting technology education (barriers to adoption) and three suggestions of things that should be done to strengthen technology education in New Mexico. Items for these checklists were developed from pooled responses to the open-ended questions on a pilot test. The researchers also made a judgment on which of the Variables Determining the Rate of Adoption each checklist item best matched.

A panel of experts made up of two teacher educators, one state department of education representative, and one industry representative assessed the face and content validity of the instrument. A pilot test was conducted to assess instrument reliability, refine individual items and to ensure accurate interpretation of the instrument's instructions. The pilot test was administered to 25 randomly selected technology education and industrial arts teachers from among those in the population, but not chosen for the sample. Seventeen teachers responded to the pilot test. Cronbach's alpha reliability coefficients of the indices for level of adoption of technology education, perceptions of the attributes of technology education, and influence of change agents and opinion leaders on adoption were .88, .80, .77, respectively. Data were collected from October to December 1998 following the Dillman (1978) Total Design Method of implementing mail surveys. Magnetic rulers were sent as incentives with the two mailings to increase the response. These procedures yielded a 66% (*n*=112) response of which 58% (*n*=98) were usable. To check for non-response bias, ten (17%) of the non-respondents were called and administered the entire questionnaire over the telephone. Their data were pooled with the data of two respondents who responded long after the deadline. Using *t*-tests, these non-respondents and late respondents were compared statistically (α=.05) to the respondents on the level of adoption of technology education, perception of the attributes of technology education, and age. Respondents had significantly lower levels of adoption of technology education, lower perceptions of the attributes of technology education, and were older than the non-respondents and late respondents. Therefore the non-respondent/late respondent data were not pooled with respondent data since they appear to be different. The researchers therefore recommend caution in generalizing the results of this study beyond the respondents.

Results

Factors predicting adoption of technology education were determined using stepwise multiple regression. A probability level of .05 was used as the criterion for accepting a factor into the prediction model for level of adoption of technology education. Subordinate objectives one, two, and three were analyzed with descriptive statistics. Answers to the three checklists were reported as frequencies and percentages. Because they set the stage for the major analysis, the subordinate objectives will be discussed first.

Subordinate Objective One

A total of 78.4% (*n*=76) of the teachers were male and the remaining 21.6% (*n*=21) were female. The minimum age recorded was 25 years old and the maximum age was 77. The average age of the teachers was 45.94 years (*SD*=9.47).

A total of 12 teaching endorsement categories were listed on the survey based on pilot test data. After a preliminary analysis of the level of adoption of technology education, a dichotomous variable was created from the 12 categories. It consisted of teachers who held either an Industrial Arts and/or Technology Education endorsement (*n*=69, 71% of the teachers) and teachers who did not have either endorsement (*n*=28, 28.9% of the teachers).

Only 56 (57%) teachers responded to the program budget question. The minimum budget amount given was $0 and the maximum was $9,999. The average budget was $2,213 (*SD*=$2,261). Because so little data were obtained for this variable, a new dichotomous variable for program budget was developed for the regression analysis based on responses to the “inadequate budget” item in the barriers to adoption checklists. Fifty-six (57%) of the respondents indicated that an inadequate budget was a barrier to adoption while forty-two (43%) did not. Most teachers indicated that they taught at more than one grade level. After preliminary analysis, grade level was also collapsed into a dichotomous variable. A total of 65% (*n*=63) of the teachers were teaching only at the high school level (grades nine, ten, eleven, and twelve) while the remainder taught at least some

of the time at the middle school level (grades six, seven and eight). There were 96 teachers who
responded to the item on years of teaching. The values ranged from one to 41 years. The mean was 15.44 (*SD*=9.49).

Subordinate Objective Two

The teachers' perceptions regarding the attributes of technology education as an innovation were measured with ten, Likert-type scale items. The values could range from 1 to 5. With ten items, then, the composite values could range from 10 to 50. The lowest composite score among the respondents was 22 and the highest was 48. The mean was 34.29 (*SD*=5.25). Respondents averaged a 3.43 across the five-point scales, indicating a neutral attitude on the part of the teachers regarding the attributes of technology education as an innovation.

The mean perceptions of how often the different types of program decisions are made were 3.69 (*SD*=1.08) for optional decisions (corresponding to "most of the time" on the five-point Likert-type subscale), 2.91 (*SD*=1.01) for collective decisions (corresponding to "sometimes"), and 2.69 (*SD*=1.15) for authority decisions (corresponding to "sometimes").

The mean composite perception of the influence of change agents and opinion leaders in adopting technology education was 25.21 (*SD*=5.17). Since there were eight Likert-type items that made up the composite value, the range was from eight to 40. The range of values for the respondents was from 15 to 38. The average value per item was 3.15 on the five-point scale, indicating that change agents and opinion leaders had a slight influence on adopting technology education. The lowest and highest scores recorded for the index were 15 and 38, respectively.

Subordinate Objective Three

Eighteen items were developed to measure the level of adoption of technology education on a seven-point scale. Thus, the possible range of values was from 18 to 126. The actual values ranged from 56 to 122. The mean composite level of adoption of technology education among the respondents was 96.1 (*SD*=12.64). The mean value per item was 5.34. This indicated that the respondents were implementing technology education only to a slight extent.

Primary Analysis

Before the primary analysis was conducted, a scatter plot of the data was produced. Two outliers among the respondents were identified and removed. This left responses from 93 teachers for the final analysis. A stepwise multiple regression procedure was then performed resulting in a mathematical model that explained 44% of the variance in level of adoption of technology education. The model included six independent variables that reached the criterion alpha level of .05. These predictors were:

1. Perceptions of the attributes of technology education as an innovation.
2. Influence of change agents and opinion leaders.
3. Perception of how often "optional" program decisions are made.

4. Perception of how often "authority" program decisions are made.
5. Teaching endorsement held.
6. Years of teaching.

The prediction equation for this model was $Y = .89 (X_1) + .58 (X_2) + 3.92 (X_3) + 2.58 (X_4) + 6.59 (X_5) - .2596 (X_6) + 28.7216$. The subscripts in the equation correspond to the numbers in the above list. Endorsement status used dummy coding with those having endorsement in technology education and/or industrial arts assigned a 1 and those without assigned a 0. Note that the relationship between level of adoption of technology education and years of teaching experience runs in a negative direction, meaning that those with more teaching experience are less likely to have implemented technology education. The results of the regression analysis are reported in Table 1.

Table 1
Factors Predicting the Adoption of Technology Education by Secondary Technology Education and Industrial Arts Teachers in New Mexico (n=93, two outliers removed)

Independent Variables	Parameter Estimate	Standard of Error	Type II Sum of Squares	*f*	*p*
Intercept	28.72	10.72	631.93	7.18	.01
X_1 – Perceptions of the attributes of technology education	.89	.22	1444.57	16.42	.01
X_2 – Influence of change agents and opinion leaders	.58	.22	622.44	7.07	.01
X_3 – Perception of how often optional program decisions are made	3.92	1.26	855.03	9.72	.01
X_4 – Perception of how often authority program decisions are made	2.58	1.18	418.04	4.75	.03
X_5 – Teaching endorsements held	6.59	2.29	726.07	8.25	.01
X_6 – Years of teaching	-0.26	0.11	490.73	5.58	.02

(Adjusted R^2=.44, p=.01 for this six variable model)

Barriers and Promoters of Change

As mentioned earlier, teachers were asked to indicate perceived barriers, as well as promoters, to the implementation of technology education. An inadequate budget was indicated as a barrier by more respondents than any of the other choices (*n*=56). This was followed by inadequate facilities (*n*=50) and inadequate resources (*n*=43). Other frequently cited barriers were inadequate educational programs to learn about technology education (*n*=32), fear of change (n=30), lack of incentives to change (n=23), and inadequate administrative support (n=20).

Personal interest was cited as the most common promoter to adopting technology education in New Mexico (n=56). This was followed by workshops (n=38), and being able to visit functional technology education programs (n=29). Other promoters with high frequencies were the availability of grant funding (n=26), school-to-work initiatives (n=25), state level support (n=24), opportunity for professional advancement (n=18), and peer teachers (n=15). These data are reported in Table 3.

Interestingly, while 56 and 43 respondents respectively, indicated inadequate budget and resources as barriers to adoption (Table 2), 26 respondents indicated available grant funding as a promoter of adoption (Table 3). Also, respondents indicated state level support both as a promoter (n=24) and as a barrier (n=16) to adoption.

Table 2
Barriers to Adopting Technology Education in New Mexico

Category	*n*	%	Rank	Primary Determinant (Rogers, 1995)
Inadequate budget	56	19	1	Relative advantage
Inadequate facilities	50	18	2	Compatibility
Inadequate resources	43	15	3	Relative advantage
Inadequate educational programs about technology education	32	12	4	Change agent efforts
Fear of change	30	11	5	
Lack of incentives to change	23	8	6	Relative advantage
Inadequate administrative support	20	7	7	Change agent efforts
Inadequate state level support	16	6	8	Change agent efforts
Unfavorable publicity about technology education	7	2	9	Change agent efforts

The most frequent suggestions for strengthening technology education in New Mexico were increased funding (n=79), development of financial incentives (n=38), and increased state level support (n=35) (Table 4). Other frequently suggested improvements were increased industry support (n=32), improved pre-service education programs for technology education (n=27), increased in-service opportunities (n=22), increased administrative support (n=21) and sponsoring more conferences to share ideas (n=11).

Overall, the results from the three checklists support the regression model in that the perceived attributes of technology education and influence of change

Table 3
Promoters of the Adoption of Technology Education in New Mexico

Category	*n*	%	Rank	Primary Determinant(s) (Rogers, 1995)
Personal interest	56	22	1	Compatibility
Workshops	38	15	2	Change agent efforts
Visiting technology education programs	29	12	3	Observability
Available grant funding	26	11	4	Relative advantage
School-to-work initiatives	25	10	5	Compatibility
State level support	24	10	6	Change agent efforts
Opportunity of professional advancement	18	7	7	Relative advantage
Peers	15	6	8	Communication channels/ opinion leaders
College courses	11	4	9	Change agent efforts
Phasing out of industrial arts	3	1	10	Relative advantage

Table 4
Suggestions to Strengthen Technology Education in New Mexico

Category	*n*	%	Rank	Primary Determinant (Rogers, 1995)
Increase funding for technology education	79	28	1	Relative advantage
Develop financial incentives	38	14	2	Relative advantage
Increase state level support	35	12	3	Change agent efforts
Increase industry support	32	11	4	Change agent efforts
Improve pre-service education programs for technology education	7	10	5	Change agent efforts
Increase in-service opportunities	22	8	6	Change agent efforts
Increase administrative support	21	7	7	Change agent efforts
Add more conferences to share ideas	11	4	8	Change agent efforts

Build the Technology Student Association	6	2	9	Compatibility

agents and opinion leaders on the adoption of technology education appear in both the regression and checklist analyses. In Tables 2, 3, and 4, three of the attributes of technology education (i.e., relative advantage, compatibility, and observability) are represented, as are the influences of change agents and opinion leaders (peers) on adoption.

Conclusions

The teacher respondents were mostly males and averaged 46 years of age. Their program budgets averaged $2,212.54. Industrial Arts, Technology Education, and Science were the most common endorsements held by the respondents. The majority of the teachers taught only in grades nine through twelve. The remainder of teachers taught at least some of the time in grades six through eight. Their years of teaching experience ranged from one to 41 years and averaged 15 years.

Overall, the teachers had a neutral perception of the attributes of technology education as an innovation. Most of the time, program decisions are made by individual teachers (i.e., are optional decisions). Collective decisions (made by the teacher and others) and authority decisions (made by others) about programs are sometimes made. The teachers saw change agents and opinion leaders as having a slight influence on their adoption of technology education.

The best predictors in this study of the level of adoption of technology education from among the independent variables studied were: perceptions of the attributes of technology education, influence of change agents and opinion leaders on adoption, perception of how often optional program decisions are made, perception of how often authority program decisions are made, teaching endorsements held, and years of teaching. These six variables explained 44% of the variance in level of adoption of technology education.

The five most frequently cited barriers to teachers adopting technology education in New Mexico were: inadequate budget, inadequate facilities, inadequate resources, inadequate educational programs about technology education, and fear of change. The barriers correspond to relative advantage, compatibility, and change agent efforts from among E. M. Rogers' (1995) determinants of the rate of adoption of an innovation.

The five most frequently cited promoters for adopting technology education in New Mexico were: personal interest, workshops, visiting technology education programs, available grant funding, and school-to-work initiatives. These promoters correspond to compatibility, change agent efforts, observability, and relative advantage from among E. M. Rogers' (1995) determinants of the rate of adoption of an innovation.

The five most frequently cited suggestions for strengthening technology education in New Mexico were: increase funding for technology education, develop financial incentives, increase state level support, increase industry support and improve pre-service education programs for technology education (Table 4). These suggestions for strengthening technology education correspond to relative advantage and change agent efforts from among E. M. Rogers' (1995) determinants of the rate of adoption of an innovation. Overall, items corresponding to attributes of technology education and change agent efforts are frequently cited in all three checklists. The availability of resources appears to be a key factor overall in the adoption of technology education.

Recommendations

As mentioned earlier, there is evidence that non-respondents differ from the respondents to this study. Once again, the reader is cautioned to keep this in mind as generalizations are developed.

The strongest predictor of the level of adoption of technology education was the perception of the teacher of the attributes of technology education. This suggests that in order to encourage the adoption of technology education, change agents should focus their efforts on increasing teacher perceptions of the compatibility, relative advantage, trialability and observability of technology education and decreasing perceptions of its complexity.

Considering compatibility, there are some practices that change agents might consider. First, show how technology education can be integrated into an existing system. For example, a teacher might visit an industrial arts program that is successfully making the transition to technology education. Second, show how the curriculum practices of the targeted teacher that are already in place match the technology education paradigm. Third, show how current teaching practices can be expanded to incorporate cooperative learning and measure learning processes as well as products.

To facilitate the change to technology education relative to the teachers' perceptions of relative advantage, incentives for adoption might be increased. These could include awards, travel resources, and released time for learning about the program. Second, teachers could be made aware of opportunities for funding and encouraged to pursue them.

Concerning the trialability of technology education, arrangements could be made for in-service workshops and conferences throughout the state incorporating hands-on activities that could be taken back to the classroom and implemented. Second, the teachers could be provided with curriculum and instructional materials that are understandable and easy to use.

Regarding the observability of technology education, change agents might use pre-service and in-service programs and professional communications to arrange for teachers to travel to other states to observe successful technology education programs. Furthermore, ongoing programs that show the successful implementation of technology education might be showcased for other teachers to observe.

To reduce teachers' perceptions of the complexity of technology education, the diffusion process should be started slowly with small, easy-to-understand modules or other components of technology education. As teachers gain experience and have success, the more complex components could be added.

Resources were clearly important in the implementation of technology education in New Mexico. Change agents should work with administrators to assure adequate resources and to help them better understand what technology education is.

In this study, perceptions of how often optional and authority program decisions are made were both predictors of the adoption of technology education. Change agents should be made aware that a combination of teacher decision making and decisions made by a higher authority like a state supervisor or principal may lead to the highest level of adoption of technology education. Although the perception of how often collective program decisions are made was not a predictor of the adoption of technology education, it did have a low positive relationship with the level of adoption. Therefore, pending further investigation, the researchers recommend that collective decision-making also be encouraged when appropriate for making decisions about technology education and industrial arts programs.

Those teachers endorsed in technology education and/or industrial arts had a higher level of adoption of technology education than those endorsed in other areas. Collegiate programs that produce teachers with technology education endorsement must be supported. Moreover, school districts should be encouraged to hire teachers with a technology education endorsement. Years of teaching experience was a predictor of adoption of technology education. The fewer the years of teaching experience a teacher had, the higher their level of adoption of technology education. The study did not determine why this was so. However, a plausible reason is that new teachers are more likely to be educated in technology education than veteran teachers. If this is true, then it argues for strengthening in-service education programs and support to veteran teachers.

The influence of change agents and opinion leaders on adoption was a predictor of the level of adoption of technology education. As mentioned earlier, change agents should be made aware of the other variables related to the level of adoption of technology education and the implications of those relationships. They should also focus on eliminating some of the barriers to teachers adopting technology education and take advantage of the promoters of adoption of technology education. Change agents should be aware of their key role in making the transition from industrial arts to technology education happen.

As a state, New Mexico is progressing toward the adoption of technology education. For traditional industrial arts teachers, the transition process has been difficult. The state department could direct efforts toward those teachers who do not appear to be willing to make the change to technology education. The process should be gradual and emphasize the similarities between elements of existing practice and what is expected in technology education. Progress should be recognized and rewarded. Efforts to reduce fear in the change process are essential.

E. M. Rogers' theories regarding the change process appear to be applicable and useful to understanding the transition to technology education. Other variables that might explain the variability in the adoption of technology education should be included in future studies to strengthen the prediction equation. More effort should also be directed at the decision making process and how it affects the change to innovative curricula. More specific information is needed on the influence of resources and the long-term adoption of newer educational programs such as technology education.

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Confidence! Its Role in the Creative Teaching and Learning of Design and Technology

Trevor Davies

Educational context

There is a well-established link generally between achievement and self-confidence in creative teaching and learning which good teachers both recognize and attempt to promote. Kimbell et al. (1991) found that confidence is an important contributor to success in design and technology. In Fryer's (1996) research, which involved 1028 teachers and lecturers, concluded:

> Just about all the staff said that they thought that building children's confidence was crucial to the development of creativity. There can also be a self-fulfilling prophecy effect according to a social work lecturer: 'if you tell people they are creative, they are more likely to be creative.' (p. 82)

In the United Kingdom, over recent years since the implementation of the Technology Order as a component of the 1988 Education Reform Act (Department for Education, 1990), the role of Government has been central in determining what is taught through the National Curriculum. It has also indirectly been in control of how teaching takes place through the regular inspection procedures by the inspection agency, OFSTED (Office for Standards in Education). This affects all state schools and all teachers. Ownership of teaching processes has in part been taken away from schools and teachers who are anxious to ensure that their schools and teaching are seen in best light. There is a competitive culture where parents and students strive to gain entry to the "best schools" on the basis of the information available, which includes tables of standardized assessment results and publicly available inspection reports on each school. Kimbell (1997) discussed in detail how the unraveling of the National Curriculum assessment structures disempowered design and technology teachers by not supporting a holistic approach to teaching and assessing the subject. It created a cumbersome bureaucracy while producing less trustworthy information than before. This is particularly disturbing for design and technology for which the heart of the matter is often thought to be creative thinking and problem solving. Among teachers, there is a widely recognized difficulty of balancing the teaching of "skills" and promotion of creative

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responses from learners. Kimbell (1996), writing about the role of the government in design and technology classrooms, feels that:

> …the centralizing influence of a national curriculum runs the risk of placing a dead weight on innovation—discouraging imaginative teachers and schools from developing their curricula. (p. 99)

The problem has been recognized by the Secretaries of State for Education and Culture, Media and Sport, the Rt. Hon. David Blunkett, MP, and the Rt. Hon. Chris Smith, MP, who set up the National Advisory Committee on Creative and Cultural Education (NACCCE) in February 1998. Its terms of reference were that the Committee should take stock of the current provision for creative and cultural education in formal and non-formal education, including that for design and technology, and to make proposals for principles, policies, and practice. In his forward letter in the report (Department for Education and Employment, 1999), the Rt. Hon. David Blunkett, MP, begins, “Creative and cultural education can help raise educational standards by boosting a child’s confidence and self-esteem.”

Research Methodology

The philosophical basis for this research is phenomenological in the sense that it was intended to examine creativity as a phenomenon construed by teachers and learners in the context of design and technology. Phenomenology is described by Polkinghorne (1989) and Hussel (1931) as having its origins in “an exploration of the structures of consciousness in human experiences.” Cresswell (1998) applied it more recently and extensively to a full spectrum of human sciences for research and development purposes. The findings concerning the contribution that confidence makes to creative teaching and learning in design and technology education are explained and then considered in the light of what is contained in literature.

The research was designed to reveal relevant constructs (personally constructed meanings) based on the experiences of students and teachers and their understanding as determined through discussion and clarification. The methodology involved using semi-structured interviews with teachers and learners in ways which enabled them to recount in detail their experience of a phenomenon like creativity, for example. They were designed to give maximum opportunity for respondents to be reflective about their experiences of creativity resulting in responses that made explicit their values, interpretations, and judgements. Phenomenology is concerned with the “science of essential being” dealing with “essences,” not “facts” relating to the individual constructs around which individuals build their worlds.

An independent secondary school for girls was selected to host the research. The decision was based on the design and technology department prioritizing the phenomenon (creativity) and the school was eager to use the research for self-development. The results used in this paper were derived from recorded, semi-structured interviews with three teachers fictitiously named Sheila, Helen, and Ray. These teachers had major interests in textiles, food, and resistant materials respectively. Six students were also involved with the fictitious names of Ann, Brenda, Carey, Dianne, Ewan, and Fay.

In order to access the private worlds of respondents, a research technique was derived from Personal Construct Psychology (PCP). Central to the meaning of PCP is the notion that we all construe our worlds and approach new problems in ways that reflect our experiences (Kelly, 1955). Each teacher selected up to six products that students had designed and made which they as teachers found interesting in some respect. The "link" between interesting and creative was made during subsequent interviews when these products were used as elements to build repertory grids (see Pope & Denicolo, 1993; Yorke, 1978). Each grid consisted of a map, graphically presented, of each respondent's constructs that were derived and recorded through a close examination of the elements. The constructs (personally constructed meanings) of each respondent about their experience of teaching, related to the circumstances of the learning resulting in the products, were explored. The grids were constructed during each interview for which transcriptions were subsequently analysed. This involved identifying a construct with the teacher that was thought to be important in relation to all of the products. For example, Helen decided that students took risks with their products. An emergent pole and a contrast pole were then identified, forming the two ends of a continuum for measuring the construct. The emergent pole in this case was determined to be "high risk-taking" and the contrast pole considered to be "low risk-taking"; high risk was graded as 1, low risk as 5. Two products were identified that were similar with regard to the level of student risk-taking and one that was completely different in accordance with a particular construct. Subsequently, all products were graded by Helen on a previously agreed scale of 1-5 as to the perceived level of risk-taking associated with each product. Interviews with two or three students, whose work was considered in each teacher interview, were then conducted along simplified, but similar lines. They each brought the selected piece from the teacher interview and five further products manufactured at school or at home. With students, the approach was adapted from a methodology developed by Salmon and Hilary (1984), and was specifically developed for use with children. Their study involved Year 8 learners in design and technology classrooms and involved using a simpler grading procedure.

The method enabled teachers and subsequently students to discuss their constructs freely. Evidence of the assumptions and principles that were behind their judgements were sought and recorded. A great strength of the method was that this particular style of interviewing helped respondents to clarify their ideas through bringing to the surface buried knowledge, feelings, and beliefs.

Data Analysis

Repertory grid data were analyzed using REPGRID software, which allows the responses of each teacher and student to be numerically and graphically analyzed to show patterns and relationships in the constructs that each holds. Interviews were transcribed and coded in detail using NUD*IST 4 qualitative analysis software. The efficient sorting and searching facilities of this software allows patterns in constructs within and across data-sets to be found and theories to be built and tested. The phenomenological tradition for data analysis was followed. This involved a gradual reduction of the data into clusters of common constructs and eventually identifying the essential invariant structures or essences (Moustakis, 1994; Polkinghorne, 1989) which comprised the main common threads of meaning and response. This revealed information about the contribution that creativity made to design and technology for the respondents. Two matrices of construct groups were drawn up as a result of the interview analysis. The constructs related to their "common" perceptions of what was important for creativity in teaching and learning. The matrices indicated the relative frequencies that respondents reported particular strengths and weaknesses in connection with each construct, and compared the responses of teachers and students. The matrices were:

1. The construct group relevant to "creative teaching to support creative learning":
   - the construction of relationships between teachers and learners,
   - teachers' personal creativity attributes,
   - teachers' approach to dealing with knowledge,
   - teachers' delivery styles.
2. The construct group relevant to "creativity and student learning":
   - student personality attributes,
   - cognition and creativity,
   - opportunities for creativity,
   - student approach to learning.

The results that follow elaborate on a summary of the evidence distilled from an analysis of the matrices. They indicate the relationships between teacher/learner confidence and the perceived strengths and weaknesses present that enabled creativity to be an important part of teaching and learning. The role of confidence generally is the overarching theme.

Results

Difficulties with promoting creativity in students' work

All three teachers felt that they were capable of being creative in some aspects of their personal lives and hence felt that they generally understood what being creative meant, even though this understanding differed among the teachers. It was significant that none of the students commented on the creativity of their teachers, hence they did not recognize them as role models or mentors in this respect. All three teachers felt that creativity has a role in the teaching and learning of the subject, but a subservient one to the development of knowledge and skills. They were confident that their knowledge of the subject was good, as was their command of key skills. In practice, they admit that they emphasize the areas of knowledge and skill with which they as individuals are most confident. The teacher's views were shaped by concerns about:

- their own interpretation of what constitutes creativity;
- their own personal, "self-perceived" levels of creativity;
- wasting time when assessment goals need to be achieved.

The students were negative about the interest and relevance of some of the activities. They did, however, agree with teachers who said they prioritized rigorous critical testing and evaluation, valued originality, and, to a certain extent, encouraged self-expression. There was a strong feeling by the teachers that, in practice, they were unable to support student risk-taking or encourage originality because of the pressures on them to minimize failure of all types, so as to not allow any "performance deficiencies" to be perceived by institutional and public agencies:

> Sheila: "…it is not always possible to register their levels of originality."
> Helen: "I think a large part of my role is that I have to meet the regulations of the National Curriculum."

Sheila is prepared to accept that her students might be more creative than she, and is more sensitive than the others to recognizing that she could learn from them. Ray is anxious to promote creativity, but feels that he is not very creative himself. Sheila expressed concerns about teaching screen printing, as did Ray with electronics, based on a lack of personal confidence in these subject areas. As experienced teachers, they are confident working with students, with the exception that Sheila is more anxious than the others about not identifying, and hence supporting, creative student work in an appropriate way. Both Sheila and Helen however, feel that the development of products with function and form that has incorporated imaginative and original design are at the heart of the subject. The difficulty admitted by all three teachers, was that of satisfying their recognized responsibility for teaching processes to classes of students. All three teachers recognize the difficulties of meeting student expectations, the needs of the subject, and subject National Curriculum Order simultaneously.

Risk-taking for teachers

Teachers were not significantly conscious of being risk-takers with their personal design and technology activity, but Sheila and Helen both had histories of risk-taking in their lives that were linked to significant personal and professional development.

The success of the Design and Technology Department at the School is measured mainly through subject selection by students, on entry into public examination courses, at ages 14 and 16, and upon subsequent examination success. Both bring status and confidence for the teachers and the department. These are major influences when the teachers develop curriculum content and pedagogy. As a consequence, teachers are not willing to take any risks that might jeopardize learning and do their best to ensure that all students learn something. This raises the question as to the amount of effort this requires with learners who are not well disposed to learning. The constraints affect the degree to which teachers are prepared to trust students. They all perceive that projects that challenge students are "high risk" to support. They also perceive that students do not naturally choose difficult tasks which can lead to high achievement, instead, they often make compromise decisions that attempt to maximize success while minimizing effort.

The teachers recognize the risks they take when building relationships with students. Sheila knows that they use her as a scapegoat for any failure. She also feels that dealing with this is an essential part of her role but gives a strong incentive to offer tasks that are secure and tightly constrained:

> Sheila: "…I want them to have a go at this and sometimes they don't quite finish. They are disappointed and I find it very difficult to make them feel better about the quality of the work that they have done. I feel I carry a lot of 'blame' for this then."

In contrast, personal rewards are high when she convinces a student to take a risk who subsequently takes ownership of the process. Sheila recognizes that students firstly need to respect her as a person, secondly as a subject specialist, and finally as an examination gatekeeper. In reality, this third factor often predominates. All three teachers take risks when dealing with student value systems through imposing their own, but the pressures of the role limit the opportunity to construct value systems with students.

Reactions of learners; sources of frustration and concern

Some students construe projects as exciting overall but gain limited enjoyment from manufacturing due to fears of working with the equipment, such as drills and saws. This can lead to a loss of interest in the subject overall and is difficult to overcome.

Ann and Fay admit low confidence levels and shy away from high-risk strategies that contain a chance of failure, even though they both recognize that are capable of taking more imaginative approaches to their work. Fay is a bright articulate student who has superficially convinced herself that success in the subject doesn't matter. Dianne understands the relationship between achieving quality results and taking risks with ideas. She is prepared to spend time and effort dealing with complexity and to achieve simple but elegant solutions. Frustrations with her skill levels often cause her disappointment, hence pride and enjoyment is gained from success with simple tasks. Dianne admits difficulties with craft skills, but questions their educational validity.

Ann is discouraged from taking even low level risks with her approach due to perceived restrictive examination and assessment targets.

> Ann: "I don't want to get a really bad mark. It is the marks; you don't want to have something that looks really bad."

Her interview evidence indicates that this pressure leads to stifled intuition. Students do not, in general, feel that they are able to deal with the problems of the subject objectively. As a result of their lack of confidence and the nature of the expectations of their performance, emotive reactions often occur. Evidence from interviews showed low perseverance with tasks that are set since the motivational factors are limited to those linked to performance on examinations and assessments. Students do not see that the activities in which they engage are linked to a growing interest and understanding of the rest of the world around them. As a result, they do not build confidence.

When confidence levels are high, as with Brenda and Carey, they seek to learn from failure. Some rationalize the relationship between learning and failure, but do not feel strong enough to face real challenges that match their potential and ability. They work to satisfy themselves, actively minimizing risk by ignoring the wider perspectives. Some of the greatest risks felt by students relate to satisfy their peers. Carey does not want to lose face or credibility by doing something that others might construe as stupid or of low worth. This can greatly affect performance in group work, as in Ann's case elaborated above. Students such as Brenda can be very intolerant of peers.

The importance of student ownership

Ann and Ewan both construed that teachers value only the outcomes from the activities that they themselves introduced and supported as part of their curriculum experience. They feel that this was a way in which teachers justify their role. All of the teachers agree that there is a limited emphasis on promoting self-directed learning and that the constraints governing their work does not allow this to happen. On the other hand, the teachers believe that they offer good mentorship to students. But this is in contrast to the students' belief who agree additionally that there is little opportunity for self-directed learning, desire it as a priority, and often do not relate to the priorities that teachers set. Students such as Dianne recognize the need for close, individual teacher support, as she articulates the difficulty of getting her ideas out into the world. She knows that she needs the help of teachers to achieve this through identifying what is reasonable to achieve and what is not. When teachers are perceived to be insensitive to this problem, students react in negative ways to them as individuals. There is a strong response from a number of students such as Ewan that good teachers enhance their own feelings of pride about good achievement:

> Ewan: "…I spent a lot of time working through my ideas which I thought were quite interesting. I spent a long time thinking about how I would like it, but the teacher didn't seem to think much of it, so I didn't make it as good as maybe I could have made it."

This occurs through recognizing "what is good work for them" as individuals. Fay feels that she produces her best work only if she has the support and endorsement of her teachers. Overpowering, authoritative approaches from teachers are also vehemently rejected.

Teachers are committed to encouraging student self-expression, but linked to students taking a thoughtful approach to their work. There is a measure of agreement between teachers and students that originality is encouraged and supported where possible, which leads to students such as Dianne and Fay being more confident than the others. Teachers and students know the value of skepticism in developing independent approaches to learning, but none felt confident when dealing with it. Teachers felt it to be "threatening" and students were too insecure. They generally wanted to be given answers and suggestions rather than search for answers, even though they desired control over their work.

The importance of home-based experience

From the data, teachers gave no priority to what experiences and learning students might have or be receiving outside school. More importantly, they did not take steps to understand the possible impact of any parent/student relationships that might be impacting upon student learning. In several instances, students placed a great deal of value and trust on what parents had to say which creates a tension with what teachers are trying to promote. Students indicated consistently that they followed the advice of their parents and showed an appreciation of the skills and understanding that their parents had helped them to develop, even if they were not recognized as "technologically minded." Carey has strong craft-based interpretations of the subject and frequently refers to the close link with her father:

> Carey: "I used to do that with my dad…."
> Interviewer: "Do you spend a lot of time with him doing things related to the subject?"
> Carey: "Yes; a lot."

The student is left to find, independently, a way of mediating the perceived conflict between the approaches of the people she trusts. This leads to certain insecurities and mixed feelings about some of the choices faced in and about her work. The impact of early experiences as young children with parents are of great significance with a number of students. Ewan had the benefit of a supportive, encouraging, constructive environment, with the benefit of extensive discussion about her activities. Her mother's judgments still remain extremely important to her.

Dimensions of Creativity

In order to contextualize the findings from the research, an analysis of relevant literature is now presented.

Creativity and Design

In order to solve ill-defined design problems, complex strategies are frequently used by inventors and designers, sometimes working independently, but often working in teams. Barak, Maymon and Harel, (1998) discussed why teamwork has become increasingly important in modern industries:

> Another factor that has created the need to work in teams is the information explosion and the need to solve issues that are more and more complex and multidisciplinary. (p. 86)

Personal resources, skills, vision and the ability to communicate are usually required to overcome competition and prejudice in order to appeal to the hearts and minds of potential customers. Joyce et al. (1998) noted how "innovators" and "creatives" can currently command prestigious positions at all levels in the commercial world (p. 113). Solutions are never right or wrong, only better or worse and rely often on having a "feel" for the market place, the customer base and the developmental implications of a solution in order to make good judgements and decisions. Baxter (1995) stated:

> Creativity is at the heart of design, at all stages throughout the design process. The most exciting and challenging design is that which is truly innovative; the creation of a radical departure from anything currently on the market. (p. 61)

Hill (1998) accepts this, but feels that creativity is apparent in different ways at different stages of the design process. Barak and Doppelt (1999) perceive creative thinking as "a combination of lateral and vertical thinking: a synthesis between imagination and logic" (p. 2).

The Nature of Creativity

At this stage it is important to consider what is meant by creativity and the nature of creative work that might take place in schools. Much of the historical concern for understanding the nature of creativity has been based on people thought to have special talents responsible for acts perceived to have high levels of worth. There is an agreement among seminal writers such as Koestler (1964), Feldman, Csikszentmihalyi, and Gardner (1994), and Gardner (1995) that creativity can result from planned activity, or can arise as a result of "flukes" or "accidents" within a domain of knowledge. There is closer agreement about the role of personality factors than there is about cognitive factors from their research. They record that particularly creative individuals, in order to make significant contributions to their chosen field, are often very demanding of themselves and committed to their tasks. Sometimes they can be "difficult" individuals, surrounded by tragedy and often marginalized from "ordinary" communities. Selfishness, intolerance, and stubbornness are frequently present and they enjoy complexity and asynchrony, which if not present are sought. Their work on the other hand can be breathtakingly refreshing and can energize others working in the field.

More recently in educational settings, there has been a concern to identify and promote creativity in all learners (Fryer, 1996; Beetlestone, 1998). This is the particular focus of the author's research in keeping with that of National Advisory Committee on Creative and Cultural Education in the UK that proposed a "democratic definition" of creativity:

> Creativity is imaginative activity fashioned so as to produce outcomes that are both original and of value. (p. 29) (Department for Education and Employment, 1999)

They proposed four main features of creativity:

- Using imagination, often to make unusual connections or see unusual relationships between objects, ideas, or situations.
- Pursuing purposes through having targets and reasons for working which can result in new purposes being discovered.
- Being original in comparison to their own work, the work of a small closed community such as peers or family, or uniquely original in comparison with those working historically or currently in a field or discipline.
- Judging value which demands critical evaluation and reflection; standing back and gaining an overview position (Department for Education and Employment, 1999).

The seminal work of Koestler (1964) and Feldman, Csikszentmihalyi, and Gardner (1994) showed a general agreement with this position. Creativity however belies simple definition and measurement and there are many agencies that act as stakeholders in the identification and rewarding of creative acts and processes. Csikszentmihalyi added that:

> …focusing on the individual alone when studying creativity is like studying how an apple tree produces its fruit by only looking at the tree and ignoring the sun and the soil. (p. 146)

Creativity in Schools

The attitudes held by teachers about the place of creativity in schools are mixed. It is recognized sometimes as being a powerful motivating force for teachers and learners, can be a vehicle for high levels of individualized achievement, and can offer clues to learners' development patterns. Conversely, there are so many other priorities in classrooms that tend to dominate attention such as basic knowledge and skills, codes of response and behavior, and the conduct of relationships. These can result in disrupted classrooms in that they can challenge "norms" and "order." Creativity requires "high risk" teaching strategies with a concern for a "long term view" of learner's potential, a willingness to wait for results, and the confidence to act intuitively at times. Creativity is also difficult to evaluate and assess (Fryer, 1996; Beetlestone, 1998; Cochrane, 1975), which adds to the difficulties teachers face when prioritizing creative work.

Barak and Doppelt proposed that thinking skills need to be explicitly developed as part of a technology curriculum since "higher order competencies do not happen spontaneously." This promotion should also be expressed through adopted assessment procedures. McCormick and Davidson (1996) determined, however, that teachers often feel the central concern for learners is to construct a finished product, which undermines the fostering of an understanding of the design process and the creative element that is an essential part of it. Hill (1998) recognized the need for students to interpret design activities in technological problem solving as an opportunity to explore. This exploration:

> …encourages student confidence in the freedom to explore and take risks. This confidence becomes critical when we understand that in creation and invention, there are always states of order and disorder. (p. 3)

Conclusions and Implications

There are many factors that contribute to anxieties when teaching design and technology. The teachers in this study were insecure about their understanding of creativity and their ability to exercise it even though they have views about its nature. They were unsure about certain aspects of their professional roles and realized a degree of role conflict between the interests of their department and their relationships with students. Insecurities did not usually surface and were normally screened by outward displays of professional confidence. Teachers are not universally multi-skilled in all areas of the subject and are most confident supporting work with which they are most familiar through their personal expertise. They know that it is important to keep their knowledge and skills updated and relevant to student needs and interests and are frustrated because of the difficulty in doing this.

The teachers who felt that they had made most progress in life through being risk-takers were better prepared to challenge learners at a high level and support them in risk-taking with their projects. A major concern among these teachers was that their students should avoid failure. Students were therefore not encouraged to be skeptical about success nor taught its value in the rigorous thinking and problem solving essential for creativity. The success that students experience boosts the confidence of the teacher. However, when students work beneath their potential then they tend to develop a negative, dismissive attitude about the value of the subject and its relevance. Rather, they expect to build confidence through working on challenging tasks. Fritz's (1996) studies with Australian students showed that students with high confidence going into an activity are more reflective about the learning processes they have mastered. For example, they identified transferable skills as their most important learning outcome. The desire to build confidence within areas where need is prioritized acts as a motivator for building competence. Fritz (1996) also identified a link between high levels of confidence and student independence. However, the teachers in this study did not feel able to respond to that desire for independence due to the institutional and legislative requirements that they are obliged to meet. As Davies (1999) found:

> If the teacher chooses to make decisions on behalf of a student, they might not necessarily be acting in the best interests of the student overall. If teachers and learners share the risks associated with the learning process, better quality learning is likely to be achieved. (p. 107)

Writers concerned with learning development highlight the importance of verbal and non-verbal communication in the promotion of learner's progress (Piaget, 1932; Vygotsky, 1975; Wertsch 1979). Vygotsky illustrated the importance of teachers working with learners as equal partners in an apprenticeship relationship. Rogoff (1990) developed the concept of guided participation, which suggests that:

> …guidance and participation in culturally valued activities are essential to children's apprenticeship in thinking. …Underlying guided participation is inter-subjectivity, a sharing of focus and purposes between children and their more skilful partners and their challenging and exploring peers. (p. 9)

There was little evidence that teachers felt able to develop such working practice with their students, as indeed the students did not convey any understanding or appreciation of any teacher's personal creativity. This in turn did not help to promote productive peer mentorship.

The students interviewed were impressionable and subject to a wide range of influences within and outside the school. When they felt well supported, their confidence levels were boosted and they made progress. When they feel frustrated, confidence was lost and often the teacher was blamed. In such cases they look elsewhere for their support, which is most frequently found at home. It is consequently important that teachers find out and account for the influence of parents and how this relates to student thinking. Ignoring the influence can at best induce the reaction that home experiences are not valued and at worst that the basis of the teaching and school experiences are worthless.

Students do not like to lose credibility with their peers and are reluctant to show the impact that loss of confidence makes. Hence teachers rarely read signals given by students in the right way unless they had a close relationship with them. Vygotsky (1978) proposed that children's cognitive development is embedded in social processes involving social relationships and socio-cultural tools. He suggested that when children (as novice partners), work with more skilled individuals or caregivers, they internalize the tools they require for creative problem solving. If students react negatively to the value systems that teachers promote, their response is to restrict themselves to "safe work," which they know will not jeopardize assessment results or examination success.

Barak and Doppelt (1998) noted that:

> In the era of information explosion, change, dynamism and pluralism, there is an increased need for education to equip the school graduate with higher order cognitive skills. Future society may particularly reward those who not only possess logical thinking, critical thinking and problem solving skills, but are also enterprising, innovative original and creative.

This research confirmed their view that design and technology education can play a central role in contributing to student development, but that in order for this to take place, teachers must be empowered to become effective learners themselves. The profile of higher-order cognition must be raised and a better understanding of the nature of effective mentorship developed. The result should increase teachers' understanding of the impact of parents' influences on students work and promote an appropriate culture to foster trust and shared risk-taking with them.

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The Formation of Children's Technological Concepts: A Study of What it Means To Do Technology from a Child's Perspective

John Twyford and Esa-Matti Järvinen

Constructivist theory epitomizes learning as an active, continuous process whereby learners take information from their environment and construct personal interpretations and meanings based upon prior knowledge and experience (Kozulin, 1998). In a socio-cultural interpretation, learning is understood to take part in a personalized social context. Thus, the acquisition of skills, knowledge, attitudes, and values are a process of enculturation, especially when the learner participates in authentic and context dependent activity (McCormick, Murphy, Hennessy, & Davidson, 1996; Koulaidis & Tsatsaroni, 1996). It follows that individual construction of technological knowledge occurs predominantly in socially interactive settings, which are shared with the members of the learning community, essentially through the meanings of context dependent language and actions (Gergen, 1995; Wertsch, 1991; Vygotsky, 1986).

Within the educational context, there are certain important considerations that need to be kept in mind when seeking to apply such a socio-cultural perspective to design and technology teaching. For example, technological problem solving, through a focus upon a solution, should relate to each child's real life environment, allowing the child to make appropriate and meaningful connections from it. Importantly, the children should actually be encouraged to identify technological problems, even deficient features in their everyday environment, as well as being given opportunities to apply the technological knowledge and skills which they have acquired in subsequent problem solving (Schwarz, 1996; Lehto, 1998; Adams, 1991).

In addition to the perspective above, the children should be given opportunities to act according to the technological processes required to solve the problems they face. Technological process can be claimed to have some certain and specific features which should be taken into account, regardless of the materials used (Sparkes, 1993). Children need to be educated as much in technology as through it (Twyford, 2000a).

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Purpose

The purpose of this study was to investigate empirically some essential features of children 'doing' technology (DeVries, 1999). More specifically, the study aimed to explore pupils' acquisition of technological understanding in collaborative settings, through authentic tasks in employing the principles of counterweight technology. An example of counterweight technology is the weight that "counters" the weight of the car in a lift or elevator installed in a tall building.

The study assumed that pupils make connections between their previous knowledge and skills and the given problem in order to formulate their version of a technological solution (Järvinen & Twyford, 2000). Consequently, the focus of this research was on exploring the technological processes that the children spontaneously went through when they used counterweight technology in their design and technology work.

The Study

The "Nodding toy" materials (Twyford, 2000) were introduced to a class teacher at Haapavesi Central primary school in Finland. The twelve hour assignment was taught to a 5th grade class containing 17 boys and 9 girls. The teacher used the "Nodding toy" materials to introduce experiments for his pupils to explore the idea of balance and counterbalance, especially to enable them to experience the use of counterweights. Thus, the materials were used as a stimulus for children to establish their own distinctive assignment, as well as to discover and make use of their understanding of counterweight technology.

After a class discussion about where and why counterweights are applied in things known to the children, they were required to work in groups and to find their own version of a real tool, device, or machine which used balance and counterbalance to make it operate and to be useful.

Pupils were required to freely explore their model design ideas in order to decide where and how they were going to use them and apply the idea of counterweight technology. The teacher took on the role of an observant tutor and demonstrated sensitive support for pupils in bringing about their personal ideas and knowledge (Honebein et al., 1993; Gallimore & Tharp, 1990). The pupils were also told that there were no right or wrong answers to the problems and that they were not going to be formally assessed in this assignment. Moreover, they were all encouraged to use their imaginations and personal creativity.

Method

Constructivism concerns the meanings constructed by pupils taking part in context-specific and socially situated activity through social interaction (Schwandt, 1994). Therefore, the research method employed was designed to elicit data from the socio-cultural context using semi-structured interview techniques.

The methodological perspective of the study was qualitative in nature and based on interpretative skills and inductive analysis, whereby the researchers continually explored the relationship between data and emergent findings (Ritchie & Hampson, 1996; Järvinen & Hiltunen, 1999).

The study employed an open search for categories, concepts, and patterns emerging from the children's assignment on counterbalance technology. The emergent patterns, relative to the theme of the study, were thereafter categorized and classified to enable interpretation to be made from the data (Erickson, 1986; Patton, 1990).

Data were collected by means of semi-structured interview (Hitchcock & Hughes, 1989). The interview took place one month after the project when all the pupils were available without affecting their school routine. The pupils were asked following questions:

- Could you describe what did you did in the project?
- Please explain how you applied the idea of balance/counterbalance in your work?
- Why did you make what you did?
- Where did you get your ideas from?

Photographs of the pupils' products taken during the project were used in the interview session to help them remember their work, including how they developed their designs. Interview sessions were recorded on a dictating machine.

During the transcription process, irrelevant data were excluded according to the analytic procedures suggested by Miles and Huberman (1994). During the first round of analysis, the researchers began to form an idea of the emergent phenomena relative to the theme of the study. As the analysis progressed, the researchers were continually seeking to re-explore the relationship between data and emergent findings; revisions were correspondingly made. They discussed and shared thoughts on many occasions. Data were analyzed by the researchers, both individually and collaboratively (Ritchie & Hampson, 1996). Finally the researchers reached a stage where they considered that they had investigated the data sufficiently.

Results

It was observed that the children in the study handled many variables simultaneously, including issues of complexity. It was therefore concluded that they were engaged in holistic designing, making, and using. Thus, it was believed that their conceptual understanding of technology might be revealed through assertions developed from the data. Two assertions were thereby developed, along with categories under them. The assertions demonstrate children's overall analytical skills in how they used their acquired processes of technological thinking when employing counterweight technology and their natural abilities to represent their understanding, especially through language. There was some overlap between the categories, but it was felt that it would not blur the essence of each category. Once the assertions and categories were developed from the data analysis, examples were "microanalyzed" in order to clarify the interpretative analysis process (Erickson, 1986; Miles & Huberman, 1994). This was done by the researchers independently and collaboratively to verify consistency.

Each assertion and its categories will be presented, followed by examples from the data, and then by the interpretation of the data. For ethical reasons, all names in the transcriptions were pseudonyms.

Assertion 1 (A1)

Children demonstrate their technological understanding through their acquired analytical skills.

A1—Category (1)

Spontaneously establishing a model idea by forming connections between their understanding of counterweight technology and authentic examples of devices or machines which use counterweights in their operation by means of synthesizing discussions between themselves, their teacher and their parents.

Examples of A1—Category (1)

Leena
Leena: “I learned how draw wells work in real life.”
Questioner: “Have you seen one?”
Leena: “Yes in our summer cottage.”
Questioner: “While making this model did you think about the one in your summer cottage?”
Leena: “Yes.”

Sami
Sami: “I made a lift…people are the counterweight in lift they make it go down and when they leave it goes up by the counterweight.”

Pentti
Pentti: “I made a lift….”
Questioner: “Did you know before hand how balance and counterbalance is applied?”
Pentti: “I knew it was applied in a lift somehow.”

Lauri
Lauri: “I said, ‘lets make a railway crossing barrier.’”
Questioner: “How is balance and counterbalance applied in a barrier?”
Lauri: “The bulky thing affects it.” (He explains how weighted barrier works with a bulky weight in place.)
Questioner: “Where did you get your idea from?”
Lauri: “From seeing real ones at a railway crossing—they stop cars crossing the lines before a train comes—it controls cars.”

Oskari
Questioner: “Why should the beam be weighted down?”
Oskari: “It is easier to lift up the load of water from the well. It came to mind—for both of us in the group. I worked with Lauri.”
Questioner: “Was it your idea or the teacher’s?”
Oskari: “Our idea—Lauri and mine.”
Questioner: “Did you discuss it?”
Oskari: “Yes we did.”

Malla
Malla: “We did an old fashion fish scale.”
Questioner: “Why did you make this?”
Malla: “We had to choose some work at home—to think about where counterweight technology is used at home.”
Questioner: “Was it your idea?”
Malla: “My mother helped me.”

Pentti
Questioner: “Did the idea of a draw well come from the pupils?”
Pentti: “Yes—and from the real world.”
Questioner: “What other ideas were there?”
Pentti: “Yes—like an elevator and such things.”

Interpretation for A1—Category (1). Leena, Sami and Pentti simply demonstrated their acquired knowledge, but Lauri demonstrated spontaneity in his choice of a model idea. He spontaneously and pragmatically analyzed his solution for which form of counterweight technology to model by various direct, but intuitive, means. Some children also identified and analyzed authentic devices or machines that use counterweight technology through discussion with their teacher and parents, as well as with their classmates. For example, Oskari’s answer shows evidence of discussion with Lauri, who is his peer. They clearly analyzed what they discussed to make a workable connection between their observations and the idea of counter balance. Here, model identification was through socio-cultural experience connected to peer discussion.

A1—Category (2)

Using personal abilities to analyze the whole model as a product in relation to its component parts using acquired knowledge of solutions and their uses.

Examples of A1—Category (2)

Mika
Mika: “Firstly, we constructed the supporting wooden beams and then a card plate and drilled holes in the base and put a wooden beam (axle) between the two plinths and a wooden ball used like a pulley with the counterweight the other side.”
Ville

Ville: "We constructed and sawed the base and we put the stop sign and chevron marking to make it look real."

Pentti

Pentti: "I made a lift in our group—firstly we planned it then we collected materials and cut suitable pieces out of cardboard and placed sticks between tables. We used two boxes, one for people and one for the weights to make it go up; when we took the weights off the lift went down."

Jarkko

Jarkko: "Jouni and others were good at this project because they made a lift and lift shaft."

Maija

Maija: "It was Tarja's idea to do a catamaran."
Questioner: "Why?"
Maija: "It was different to others who had moving parts in their models, which ours did not. To my mind it can be a boat without a catamaran, but the catamaran stops it toppling over. Paddling without the side boat would make it tilt more."
Questioner: "Have you tested it in water?"
Maija: "Yes, it floated."

Tero

Tero: "The most difficult part of the work was to have the right size of weight in place."

Malla

Questioner: "Why did you make your model?"
Malla: "We had to choose some work at home."
Questioner: "Was it your idea?"
Malla: "My mother helped me."
Questioner: "Why was it successful? Did it work like you expected?"
Malla: "Yes—because it is similar to a real fish scale and because it had the same purpose as the real thing—it illustrates this and therefore it is successful."

Kati

Questioner: "How might it be useful?"
Kati: "To weigh small things in the kitchen. The most difficult part was to make the fish scale; the easiest was the blue-tac fish."
Questioner: "Did you learn anything?"
Kati: "You can make many things using balance and counterbalance. You need 'good nerves' (tenacity) to do technology."

Jukka
Questioner: “Is it useful?”
Jukka: “One can learn about how it works. We can demonstrate the idea of a lift to first and second grade pupils, to explain what a lift is.”

Sami
Sami: “In lifts and draw wells, they use balance and counterbalance. People are the counter weight in a lift, they make it go down and when they leave it goes up by the counterweight in real ones there is a motor but—not in ours.”
Questioner: “Did you know about construction cranes?”
Sami: “I knew something—but I didn't know about how the counter weight is used although I knew about the cables in it.”
Questioner: “How about draw wells?”
Sami: “The counterweight lifts the bucket of water.”

Interpretation for A1—Category (2). Children understood that their models have component parts that are required to fit together to form the whole model. Maija aimed to simplify this by choosing a design that required a minimum of parts. Moreover, her explanation revealed her understanding of moving and non-moving components in a model, as well as a sense of what makes up a simple model that incorporated balance without moving parts. Interestingly, Jarkko made an observation (when he refers to “Jouni and others”) of the usefulness of component parts to the whole project.

Children gave many different personal explanations of how counter-weight technology was used, as well as how it could be employed in their chosen model of an artifact. It was clear in Malla’s response that she values the connection between her model and its real life equivalent. Importantly, according to her, this connection makes the work successful. The fact that Malla’s mother helped her to formulate the idea of a fish scale does not weaken the value of the work; the school should not act in a vacuum, but rather should be in constant interaction with its surrounding reality. Parents can be an important source of information and ideas as well.

Kati, who worked as a partner with Malla, found the fish scale useful for weighing small things in the kitchen. Jukka saw the model of a lift from an educational viewpoint, using it as a means to demonstrate the idea of counterweights to the younger children. The responses of Kati and Jukka give evidence that they are thinking divergently, at least to some extent (Feldman, 1993). Sami also made a clear connection between a real use of counterweight technology and his experience with how it worked in a model.

Assertion 2 (A2)

Children acquire technological understanding through several forms of representing their solution-focused ideas.

A2—Category (1)

Modeling ideas through craft-design activities and directly constructing a particular model.

Examples of A2—Category (1)

Oskari

Questioner: "What did you do?"
Oskari: "We found a picture of a draw well, (picture in the classroom). We didn't plan it beforehand—we just made it."

Timo

Questioner: "What did you do?"
Timo: "We made a lift with Jukka."
Questioner: "How did you begin?"
Timo: "We had a mutual idea to do a lift and we went to the wood shop and I took a motor from home and we used the marbles as a counterweight."

Interpretation of A2—Category (1). In these examples children represented their model ideas by handling both their design concept and chosen materials directly to form their product, three-dimensionally, in the form of 'craft-design' practice. For example, as Oskari says, "we just made it." Also Timo's response indicates that they have acquired the habit of handling materials directly and designing with them. They also carried out various activities while during the making process. For example, they adjusted the position of weights and other variables in their model without reference to calculations or plans. Thus, the children have acquired the techniques of classroom modeling and these personal, direct modeling skills are a vital part of knowing how to do technology in school.

A2—Category (2)

Establishing and modifying design ideas through the deliberate use of drawing and modeling prototypes to represent ideas (Kimbell, 2000).

Examples of A2—Category (2)

Jukka

Jukka: "It was interesting because we could look for, and explore, balance and counterbalance. Firstly we did something in cardboard then we did real things. We made a lift with Timo."
Questioner: "What did you do?"
Jukka: "Firstly we planned it on paper without a motor then we did put a motor in the lift and it was better."

Ville
Ville: “We did a draw-well with Lauri and Topias who had begun with the idea of a railway barrier. We drew it first then went to the wood shop. We constructed and sawed the base and we put the stop sign with chevron markings to make it look real.”

Kati
Kati: “Malla and me planned at home. We took Malla’s plan to make a fish scale, then we made a plan on paper for a fish scale.”

Interpretation of A2—Category (2). Jukka, Ville and Kati all used drawing to plan their models, whereas Jukka also used cardboard modeling to help in making his model. The children’s work was mostly based upon their personally driven, direct, everyday, technological understanding of balance and counter balance (see Assertion 1). The drawings used information about the overall form of the model. Jukka and his team used modeling, craft-design, and drawing to represent their ideas for making.

A2—Category (3)

Using everyday concepts expressed in varying forms of language used in class discussions, especially peer discussion, as well as in response to the teacher, their respective parents, and, at times, the interviewer. This category was further broken down into subcategories based upon four distinct forms of vocabulary in order to show how children represent their understanding of doing technology, as well as how they model their design ideas. Thus, students' concepts of doing technology are revealed through varying forms of their explicit use of different types of language.

Examples of Category (3). The children’s responses indicated that they were functioning at different developmental stages with reference to the principles involved, ranging from little or no understanding to complex understanding. Thus, each language form mirrors this broad developmental sequence.

Subcategory (a). No substantial understanding expressed verbally.

Salme
Salme: “We made an elephant [with Lotta].”
Questioner: “What was the D&T work topic?”
Salme: “I don’t remember.”
Questioner: “Was it about balance and counterbalance?”
Salme: “Mmm, yes.”
Questioner: “Explain about the class experiments which you did?”
Salme: “About animals in card- (Salme explains about making part of an animal to nod, but she does not give any information about the ruler experiment concerning balance). We made an elephant?”

Questioner: “Did you design it?”
Salme: “We planned it in cardboard.”
Questioner: “Was it your idea to use balance and counterbalance?”
Salme: “We thought about making the elephant’s trunk nod.”
Questioner: “Why?”
Salme: “It was Lotta’s idea.”
Questioner: “Did you learn anything useful?”
Salme: “Yes.”
Questioner: “What?”
Salme: “I don’t know.”
Questioner: “Did you know anything about balance and counterbalance in lifts and draw wells?”
Salme: “No. I didn’t.”

Interpretation for Subcategory (a). Not knowing how or what is happening is a clear indication of a lack of confidence to do technology at this level. However, children may be reluctant to talk about their work, so there may be more of an implicit understanding than is revealed here.

Subcategory (b). Direct practical understanding where the child intuitively demonstrates an ability to make something, but without a clear expression of how what they made actually works; for example, they “just do it.”

Jukka
Questioner: “Does it work?”
Jukka: “Yes, but it needs a battery—then it lifts the elevator up.”
Questioner: “How is balance and counterbalance applied in your lift?”
Jukka: “If there is not a counterweight in it won’t go up.”
Questioner: “Why did you make a lift?”
Jukka: no answer
Questioner: “Did you have a common discussion about lifts?”
Jukka: “Yes, at the beginning of the project, and then we decided to make a lift.”

Malla
Questioner: “Can you find your own work in the pictures?”
Malla: “Yes—we did an old fashion fish scale. We put a counterweight on the end of the beam and then you can change the position of it.”
Questioner: “How is balance and counterbalance applied in this scale?”
Malla: “You can weigh things and this is just an example of a scale.”

Interpretation for Subcategory (b). Children know what they are doing but do not clearly indicate this in the vocabulary they use to describe their actions and decisions. They have only part of what is needed to apply their knowledge to making something work in a particular way.

Subcategory (c). Using everyday language to signify a clear understanding of the technological concepts involved.

Lauri

Lauri: "Firstly, the other group members had ideas. Then I said, 'Let's make a railway crossing barrier.'"
Questioner: "How is counterweight applied in a barrier?"
Lauri: "The bulky thing affects it." (He explains how weighted barrier works with a bulky weight in place.)
Questioner: "Where did you get your idea from?"
Lauri: "From seeing real ones at a railway crossing—they stop cars crossing the lines before a train comes—it controls cars."
Questioner: "Was it your idea?"
Lauri: "Yes."
Questioner: "Did you discuss the barrier in the common discussion?"
Lauri: "No. It was my idea."
Questioner: "How could it be made better?"
Lauri: "The pivot in the beam was stiff, and to make it work better we could put more counterweights in the beam" (to overcome friction in the beam and pivot).
Questioner: "If you shorten from 'a' to 'b' what happens?"
Lauri: "The beam goes up quicker because there is more weight on the other side."
Questioner: "What did you learn?"
Lauri: "Nothing very new for me."
Questioner: "So you know about balance and counterbalance in barriers?"
Lauri: "Yes."
Questioner: "…and in cranes or lifts?"
Lauri: "Yes—I know that."

Ville

Questioner: "How is balance and counterbalance applied to the barrier?"
Ville: "It is a customs barrier. When it is down it's not so difficult to lift because of the counter weight which makes it work. The counterweight lifts it and it makes it easier to lift."

Interpretation of Subcategory (c). The children clearly understand counterweight technology, and are able to express their personalized concepts through procedural language (McCormick, 1998). They explain things in plain, everyday words. They can talk about how they made their models to exemplify appropriate application of counterweight technology. They can also talk about the usefulness of things, how they can be made, and how they work, without resorting to a complex technical or scientific vocabulary. Terms like 'bulky thing' (in Lauri's answer) indicate understanding that is colloquially expressed. They are able to make clear connections between what they know and what they make, including applying their experience of counterweights. This is the essential way in which children model their design ideas.

Subcategory (d). Using scientific language to communicate designing and making, showing a clear understanding of the concepts involved (McCormick, 1998).

Jouni
Jouni: “We had the concept of balance and counterbalance and explored it with a ruler—putting it in balance and then placed different objects at both ends of the ruler.”
Questioner: “Did you discuss balance and counterbalance?”
Jouni: “Yes—its due to gravity.”

Oskari
Questioner: “What was the D&T theme—where did you begin?”
Oskari: “We had to make something like a balance thing.”
Questioner: “Did you use common experiments?”
Oskari: “Yes—we used a beam with a hook in it (the frame experiment), not in balance and we added some weight to make it balance.”
Questioner: “Did you discuss balance and counterbalance.”
Oskari: “I don’t remember. We did discuss gravity as an effect of balance and counterbalance and gravity is a force which pulls things down.”

Interpretation of Subcategory (d). There was some evidence among two of the students that they were using what is often taken to be scientific terminology in their descriptions of counterweight technology. For example, they used the terms gravity and counterbalance. In actuality, however, no pupil used recognizable scientific descriptions of the counterweight technology in their model making. The use of terms like balance are often taken to be precise, but in fact belong to everyday language usage.

Examples of conceptual language were evident in what Jouni said since he was beginning to be precise in his use of terminology when he mentioned the notion of gravity affecting the model system. He understood how to make a model and to employ counterweight technology. Oskari exhibited similar characteristics in his use of words concerning his understanding of gravity.

A2—Category (4)

Applying acquired skills to materials, tools, and equipment.

Examples of A2—Category (4). Applying acquired skills to materials and tools.

Mika
Mika: “We did those balance things. We had the lifts and other things using balance.”

Questioner: "How did you begin?"
Mika: "Firstly we constructed the supporting wooden beams and then a card plate and drilled holes in the base and put a wooden beam (axle) between the two plinths and a wooden ball, used like a pulley with the counterweight the other side."

Markus
Questioner: "How did you begin making the draw well?"
Markus: "We used wood and glue in it. We should have made a wooden bucket and not used a plastic glue top—for our model of a draw well."
Questioner: "How did the counterweight work?"
Markus: "The water in the bucket can be lifted by the counterweight."

Maija
Maija: "We went to the wood shop and we used plastercine for the man sailing the boat, and we used wooden sticks for the boat and its oar."

Interpretation for Category (4). The children were clearly able to identify appropriate materials for their model, as well as employ typical classroom skills in manufacturing. Their making was seen to happen through their use of chosen materials, tools, and construction techniques. For example, Mika used the term "construction" and used a drill in making his model. They all handled materials and used modeling skills to construct a model of something known to them that exhibited a real use for counterweight technology.

Discussion

Children demonstrated their acquired knowledge of the use of counterweight technology in their models in many ways, especially in how they drew from their direct experiences with actual tools and machines. Further information to aid their realization of a model was derived from class discussions involving the teacher, peers, and personal analysis. This also provided support for their development of the concept of counterweight technology. Thus, children synthesized their ideas about the usefulness of a technical principle, especially because it involved them in recalling and redefining their acquired experiences.

The study revealed that children's solution-focused technological concepts were expressed through the force of their experiences and imaginations. These internally generated responses to designing and making, including knowing the usefulness of things, represent both their abilities to be creative technologically, as well as their meta-cognitive skills and processes in acquiring such abilities. Throughout, they used the everyday terms of balance and counterweight spontaneously as examples of their language and inculturalization (Panofsky et al, 1990; Parkinson, 1999).

Thus, children's acquired analytical skills and ways of representing their understanding were intuitively based upon being able to define problems and to analyze how to make a model which used counterweight technology. They handled many variables and possibilities. The complexity of their work came from employing many skills and handling ideas, processes, and materials simultaneously. They also worked with incomplete information as they developed their model.

This study empirically revealed some of the key aspects of the characteristics of children acting technologically. It demonstrated how children make pragmatic decisions about their models with respect to their experience of making. These decisions included making adjustments and changes to their model so that it would work well. Together, these processes represent a synthesis of technological thinking in which children are constantly analyzing variables in order to form their version of a model.

Children were able to define their situation, analyze the requirements, and select a personally distinct model idea. When children evaluate a design idea, an approach to making, or a use of counterweight technology against other possibilities, they are then clearly engaged in analysis. Taking a design idea and making it work is technological analysis. Thus, the assertion concerning analytical skills revealed that children make spontaneous judgments to select and make a particular model.

The basic analytical skills outlined here reveal how children's design and technology work is founded upon how they are able to make meaningful links between what things are for and how they actually work, with respect to their design and manufacture. The data indicated that children understand through analysis how products 'afford' using counterweights (Norman, 1988). Thus, children exhibited the essential analytical skills typical of technological pursuits, based upon a synthesis of acquired experiences.

Existing knowledge, direct observations, and practical experience clearly guide analysis and are a part of their interaction with peers. Children's intuitive use of analysis and modeling in their application of counterweight technology demonstrated that there was some commonality in their experience.

Problems, issues, and decisions determine the nature of technological inquiry. The subject matter for technology can be found in many areas of human experience. The task of teachers is to reveal and make explicit the knowledge, skills, understanding, and values which comprise technology. There was support for maintaining the breadth of technological subject matter because technology is influenced more by issues and contexts rather than procedures, specific skills, or facts.

The authors advocate that children's understanding of technology can be best achieved by enabling them to work in the same spirit in which technologists work. This approach brings authenticity to classroom experiences for pupils. In technology education, it is essential that the pupils are encouraged to work and learn in a way that fosters creativity and discovery. This can be facilitated by providing an appropriate atmosphere for problem solving, one that is low in stress and allows concentration on the task at hand (Futschek, 1995). Technological problem solving is a form of reflective thinking in which the child interacts with many sources of knowledge in the process of solving a problem. The pupil's mind changes and develops through active participation. In turn, pupils are able to cause real changes in the world around them when the problems tackled are also real.

Technology is a multi-dimensional field of inquiry. It is a synthesis of many experiences and successful work draws upon a wide range of knowledge; it is not bound by subject boundaries. Thus, the authenticity of technological problems or issues demands a multi-disciplinary approach. None of these characteristics are particularly unique to technological activity, but authentic experiences for students in confronting problems and developing solutions to them are essential in its role as a player in education in general.

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Heidegger in the Hands-on Science and Technology Center: Philosophical Reflections on Learning in Informal Settings

Richard Walton

Introduction and Purpose

Unusual for the philosophy of education, this paper takes Martin Heidegger's essay of 1954 *The Question Concerning Technology* as its starting point and applies it to a practical problem which is: *Can interactive science and technology centers reveal the essence of technology to the lay visitor.* At the outset this sounds like an unusually over-specific application of Heidegger's ideas to a single special case. But the notion that the interactive science and technology center (ISTC) does provide a valid and instructive vehicle for the discussion of Heidegger's ideas, particularly in their application to education, will be maintained throughout this article. There is also a sense in which Heidegger's essay has more relevance now in the present ecologically aware age than it did when it was written in the 1950s.

In order to set this paper into context, a slight departure has been made from the path of philosophical analysis in order to identify what is meant by an ISTC and by the exhibits found therein. It is worth saying that considerable investment has been made around the world in these centers in both developed and developing nations and yet no detailed philosophical analysis has been made into their claims until relatively recently (Walton, 1998). The significance is that ISTCs bridge the many, often conflicting, domains which have been characterized as *edutainment* (Friedman, 1996, p. 16) and which make up the sector of activity where formal, informal, and non-formal education is found within the context of the leisure industry. So, despite its somewhat unusual theoretical perspective and apparently esoteric subject matter, this is essentially a paper dealing with the application of philosophical analysis to a practical situation. It also seems relevant as the breadth of the technology education community becomes broader. The recently released standards for the development of curriculum in the U. S. (International Technology Education Association, 2000) is an example of the expansion of the responsibility for technology education beyond the traditional walls.

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Interactive Science and Technology Centers

Recent years have shown a rise in the number of interactive science and technology centers (ISTCs) around the world. Persson (1996) said, "there are now several hundred centers in the US, 33 in the UK, 31 in Scandinavia, 12 in Spain, 10 in the Netherlands and six in France" (Persson, 1996, p. 55). These hands-on centers are distinguished from traditional museums in that they are concerned with "the transmission of scientific ideas and concepts rather than the contemplation of scientific objects" (McManus, 1992, following Friedman, 1989). Rennie and McClafferty (1996, p. 57) maintain that the generic term "*science center*" is often used to describe such centers in a way that does not differentiate between those centers that focus on science and those that focus on technology. Indeed, this view that "technology" is often subsumed by "science" bears witness to a more widely held view of technology as applied science (Gardner, 1994). Rennie and McClafferty adopted the pragmatic position that it is impractical to distinguish between science and technology "because typically, centres contain exhibits which concern both science and technology and the research carried out within them usually fails to consider such differences." According to McManus (1992), the environment of the ISTC is markedly different from that of other museums in that they contain "a decontextualized scattering of interactive exhibits." As is generally the case with museums and galleries, ISTCs attract a diverse range of visitors: teachers and children on organized school visits; families; children and adults singly or in groups. The ISTC is a place where visitors may indeed come with the express purpose of learning science and technology but it is also likely that a visitor may visit an ISTC simply as a leisure activity in which learning takes place as an incidental or unintended outcome (Lucas, 1983).

As informal environments in which science and technology can be learned, ISTCs present problems for the philosopher of education. The first of these problem relates to the description of what is going on in such centers with regard to learning. A brief examination of the literature reveals an alarming degree of muddled thinking. The terms *formal learning* and *informal learning* have been used to characterize the conditions in which learning takes place. Informal learning is characterized by factors such as its voluntary nature, its lack of structure, and its open-endedness while formal learning is characterized by its compulsory nature, its structure, and the preference for intended learning outcomes (Lucas, 1983; Wellington, 1990; Griffin, 1994). Such a characterization is, however, misleading in that it suggests that the mental processes involved in learning are in some way different in ISTCs than they would be in other museums or centers.

In the absence of physiological evidence to the contrary, all that can be said is that the learning which takes place in ISTCs is the same as learning which takes place anywhere else. What is different, of course, is the *situation* or *conditions* under which such learning occurs. The ISTC is an environment for learning that is different from the classroom in that the visitor is presented with a range of objects with which he or she must interact. Frank Oppenheimer founded one of the first such centers, the Exploratorium in San Francisco. He had the vision of a museum of science and technology in which exhibits would be organized around areas based upon the five senses and also "on propriosensitive controls which form the basis of balance, locomotion and manipulation" (Oppenheimer, 1968, p. 218). He continued:

> … although it seems essential that the museum be structured according to some underlying plan such as the one suggested above, it is also important that the people who use the museum not be forced to follow some preconceived pattern. In the proposed organization some people might be interested in following the domain of perception from one area to another. Some might remain rooted in just one area such as in the physics of sound or in food technology, whereas others may want to wander around the halls at random. (Oppenheimer, 1968, p. 218)

This approach reveals a tacit epistemology for such centers that knowledge can be acquired by the visitor by direct experience with scientific phenomena and technological artifacts. The ISTC aims to place the visitor in a position in which it is possible to discover, through sensory acts, new knowledge and understanding of the world. The acquisition of knowledge may be mediated by guides or explanations, but this is not always the case. Similarly, labeling may be used as an *advance organizer,* placing the activity into a conceptual framework. The situation for learning which is found in the ISTC has been distinguished from other such situations (Walton, 1998) in the following terms :

- the learner sets explicit personal goals for learning—*the learner decides what he or she would like to visit and investigate;*
- the learner participates strongly in the learning process—*learning usually takes place as a result of the visitor making a direct physical interaction with the exhibit;*
- unintended outcomes may result—*the learning which actually takes place may provoke surprise or may be unexpected from the learner's point of view.*

By comparison with the ISTC, the technology classroom is more likely to be a place where the goals for learning are defined by the teacher rather than the learner; where participation is often directed by interaction with the teacher and where fewer unintended outcomes are likely to result. However, one must not lose sight of the fact that the distinguishing feature of the technology classroom —which, from a British perspective at least, is viewed as *design* and technology —lies in the way it becomes a place where the hands-on experience of the student is principally directed towards the design and manufacture of an artifact. Thus, the experience is directed towards an act of *creation* rather than of explanation.

The artifice of the ISTC lies in organizing exhibits in such a way as to promote a feeling of individual discovery in the mind of the learner—the so called *Aha!* experience. This experience was interpreted by Vygotsky as the point where "the development curve may rise sharply and begin to run ahead of the instructional process" (Vygotsky, 1987, p. 207). This sudden transition is seen by Vygotsky as a point at which development and instruction coincide to transform any subsequent learning. By contrast, Csikszentmihalyi has identified situations in which the solving of presented problems in unlikely or artificial situations can provoke feelings of frustration and listlessness. He stated:

> I had this experience even in the Exploratorium in San Francisco, certainly one of the best museums of this sort. Most of the problems were already structured, presented, and all I had to do was follow the lead given by the card on the display, and most of it was not much fun. (Csikszentmihalyi, 1987, p. 85)

The second problem which ISTCs pose for the philosopher of education resides in the subject matter of the ISTC. These centers aim to inform the public about the ideas of science and technology. They are, as has already been stated, concept-led rather than object-led museums where the visitor's interaction with physical artifacts is central to their function. The role of the technological artifacts present within an ISTC is to act as a stimulus to thought. The visitor, after hands-on interaction with the exhibits, is expected to think differently about the world than before. This poses the question: Does the object have any significance in its own right or is its significance merely instrumental in that it becomes the means by which the visitor acquires new knowledge or understanding? This places the objects within an ISTC into a different category when compared with objects found in other museums. Artifacts such as scythes, steam engines, and horse-drawn ploughs found in a museum of agriculture form a record of that technology and also bear testimony to the cultural and historical forces which were at play at a particular time and in a particular place. These artifacts have been given a pedagogical function in bearing witness to a particular aspect of socio-technological culture. They are objects which once were used to change the world but which now bear silent witness to the changes which men and women have wrought. By contrast with such techno-cultural artifacts, many exhibits found in ISTCs are designed with the sole purpose of demonstrating or explaining scientific or technological principles. They are not used to change the world but to change the visitor's view of the world. They exist only within the culture and context of the ISTC.

Heidegger and Technology

In his lecture of 1953, *The Question Concerning Technology*, Heidegger addressed what has become a central concern in the twentieth century: What is humankind's relationship to technology? Heidegger's approach was to attempt to reveal the essence of technology. In doing so he maintained that, "technology is not equivalent to the essence of technology" (Heidegger, 1954:1978, p. 311). Indeed, Heidegger maintained that the essence of technology is bound up with revealing the totality of being; in the "laying bare" of phenomena. According to Frede, Heidegger proceeds on two levels;

> He distinguishes between (a) the "ontic" level of the factual (for human existence Heidegger introduces the special term "existenti*ell*") that is open to observation, the level of field studies for the phenomenologist, and (b) the

> "ontological" level, the phenomenological description of the deep structures that underlie and explain the ontic (for the structure of human existence Heidegger introduced the term "existenti*ale*"). (Frede, 1993, p. 55)

This means that, in Heidegger's terms, "technology" is more than the artifacts and activities that form the ontic. It can be spoken of in terms of the *mode of truth* that is the framework of possibilities which forms the essential nature of technology which is to be revealed and which gives technology its ontological sense. Superficially, this ontology of technology seems to bear some similarity with the platonic notion of the *ideal form* yet, as Guignon (1993, p. 4) pointed out, a significant distinction can be drawn between Heidegger's "substance ontology" and the traditional notion of the "metaphysics of presence." According to Guignon, Heidegger's approach challenges the idea that "reality must be thought of in terms of the idea of substance at all" (1993, p. 4). In this way it is possible for Heidegger (1993, p. 327) to claim that the essence of technology existed prior to the industrial and scientific revolutions of the seventeenth and eighteenth centuries.

This notion of the "ontological priority of technology" has gained the support of philosophers of technology such as Ihde (1979) who see in this position a counterbalance to the popular view that technology is merely applied science (Gardner, 1994). The Heideggerian view sees technology therefore as a means of understanding being. Heidegger coined the term "clearing" to represent the enlightenment through which the individual gains a transcendental understanding of being. He chose to use the word "clearing" rather than "truth" because he saw, in revealing the essence of technology, the potential for danger: the danger that we may mistake the standing-reserve of technology for the essence of technology. In other words, we may mistake the artifact for the purpose for which it was conceived. This point was illustrated by Latour as he discussed how a technological project moves from idea to artifact:

> By definition, a technological project is a fiction, since at the outset it does not exist, and there is no way it can exist yet because it is in the project phase. (Latour, 1996, p. 23)

It is important, therefore, in seeking the essence of technology, not to conceal but to reveal what is real. Heidegger's position can be summarized thus:

- His aim was to reveal the true nature of technology.
- The success of technology lies in the structures and artifacts it produces.
- The danger that lies at the heart of technology is that the visible structures and artifacts of technology act as surface details that obscure its true nature and so prevent its revelation.
- As human beings we are limited in the access we have to this revelation. We cannot see beyond our understanding of surface detail. In fact our very actions as technological beings create more obfuscatory detail.
- As human beings with the power of thought we are able to reflect upon this limitation to our understanding. Through this awareness we are linked ultimately with the true nature of technology.

Heidegger and the ISTC

At the outset, therefore, Heidegger presented a picture of technology as instrumental, as a means to an end (1993, p. 313). But, in saying this, Heidegger took pains to point out that that this does not reveal the true nature of technology, it does not reveal its essence. This raises the question, to what end are interactive exhibits built? Alongside a range of possible ends such as to entertain the visitor, to stimulate and amuse, to generate income, etc., lies the central reason which is to reveal something of the nature of scientific and technological ideas. Interactive exhibits have a reflexive quality in that they exist to exemplify and elucidate generalized principles. They exist to reveal something of the nature of science and technology. If this is indeed the case then it would seem that ISTCs act as a special case of technological artifacts which are not used to change the world but rather are used to change our perception of how the world works.

In building an exhibit to exemplify a scientific or technological principle, the exhibit designer is making real an intellectual construct or abstract idea. This act of *reification* would suggest that, contrary to the usual existentialist interpretation, *essence precedes existence*. But to say so directly would be mistaken since it would regard the exhibit as coming into being without an agent. Heidegger's notion of the ontic-ontological priority of *Dasein* (Heidegger, 1927, 1978, p. 57) implies that human beings exist as agents within a world of technological potentiality. Viewed in this way, the builder takes the "standing reserve" of wood and metal, ordering it to create an object that demonstrates some aspect of science and technology. In Heidegger's terms it is the designer who is able to challenge nature to reveal something of the essence of technology. There is a distinction between an interactive exhibit and some other technological artifact such as a lathe or a transistor radio. The interactive exhibit is designed and built with the end of encouraging reflection by the visitor upon the essence of technology while other artifacts are designed for ends extrinsic to themselves: the lathe to enable other artifacts to be made and the radio as a means of communication.

In this way the interactive science and technology center can be viewed as a useful example of the Heideggerian scheme in action. The exhibits found within such centers represent a special case or category of technological artifact which is designed and built with the specific aim of encouraging reflection upon its own essence. Of course, in most cases this is only true to a limited extent. An exhibit which demonstrates chaotic motion reveals only a limited set of ideas relating to the nature of the world and in so doing it shows only one way in which technology can be used to frame this idea. But it does show that the idea can be framed. Heidegger uses the term *gestell* to describe this act of framing, or what he called "enframing."

> Enframing means the way of revealing that holds sway in the essence of modern technology and that is itself nothing technological. On the other hand, all those things that are so familiar to us and are standard parts of assembly, such as rods, pistons, and chassis belong to the technological. The assembly itself, however, together with the aforementioned stock parts, fall within the

> sphere of technological activity. Such activity always merely responds to the challenge of enframing, but it never comprises enframing itself or brings it about. (Heidegger, 1978b, p. 325)

But, is it possible for the ISTC to seek to be a means for probing more deeply into the essence of technology or of addressing the fundamental issues which relate to mankind's responsibility for technology and its impact upon the World?

Heidegger, Aesthetics and Ecology

The development of interactive exhibitions has tended to proceed along the lines of individual exhibits which are sometimes grouped thematically but which individually isolate a particular scientific or technological idea or concept and exemplify it for the visitor. This approach is primarily reductionist in that it treats the physical world as a system that can be dissected and whose nature can be apprehended by considering its constituent parts. There are, however, interactive exhibitions that have been designed to promote a holistic view of the world and to encourage a critical reflection on the part of the visitor about mankind's relationship with the world. Two such examples are the *Labyrint* exhibition developed in the Slovak Republic, and the *Earth Gallery* at the *Earthcentre* in the United Kingdom. *Labyrint* is comprised of a series of interactive installations, many of which are made up from the detritus of technology—rusty metal, broken equipment, etc.—in juxtaposition with living organisms. The visitor interacts with the exhibits through movement, sound, and light. The exhibition was set up with an expressed aim, as stated in the guide:

> The exhibition is intended as a dialogue between the rational and the emotional. Natural Phenomena and technical discoveries are presented by means of very impressive sculptures as working three-dimensional exhibits produced mainly from waste metal. The visitor can play and make [their] own experiments. …The exhibits touch basic universal concepts such as chaos, order and prediction; dynamic balance and equilibrium; microscopic and macroscopic world; mutual relations and values. (Teplanova, 1996)

In a similar vein the *Earth Gallery* evokes the spirit of the Earth and its natural environment through moving abstract forms. Glass monoliths suggest the changing seasons with rusted metal bringing to mind change and decay. Both exhibitions depart from the mainstream of interactive collections in that they use art installations to encourage the visitor to reflect upon the nature of the natural world and of mankind's interaction with it. The use of art in the interactive setting is significant from the perspective of Heidegger's work. Heidegger looks back to the *Nicomachean Ethics* of Aristotle (Book 6) in identifying the common features of art and technology in which both are seen as revealing truth.

> There was a time when it was not technology alone that bore the name *techne.* Once the revealing that brings forth truth into the splendor of radiant appearance was also called *techne*. …There was a time when the bringing-

> forth of the true into the beautiful was called *techne*. The *poiesis* of the fine arts was also called *techne*. (Heidegger, 1978b, p. 339)

So, it is not inappropriate—indeed it is probably desirable—that ISTCs should incorporate artistic work into their exhibitions. The use of art objects within a science museum was advocated by Oppenheimer (1990) who saw a complementary approach across the disciplines in the work of artists and scientists. It should be noted that this contrasts strongly with the view put forward in C.P. Snow's *Two Cultures and the Scientific Revolution* that scientists and artists view each other across a cultural divide—a commonplace notion in academic thinking in the United Kingdom. Hein, in describing the artist-in-residence program at the San Francisco Exploratorium, makes the point that distinctions between works of art and of science are not always so sharply drawn.

> The Exploratorium has established a reputation as a science museum. Although that commits it to displaying the findings of science and the techniques and instruments that make them possible, it does not prohibit exposure of uncertainty and doubt. It also does not preclude showing the complementary perceptual discoveries and the intellectual and imaginative creations that artists, using different tools and methods, continue to reveal. (Hein, 1990, p. 170)

In saying this Hein is demonstrating a practical approach which parallels the view, present in Heidegger's work, in which both art and technology are seen as means of bringing forth truth. This interpretation of Heidegger's work has great significance for museums of science and technology for it means that art can be used to make a valid commentary upon the nature of technology. Indeed it is through the art installation form of interactive exhibit that we can actually get much closer to revealing the essence of technology than we do with those exhibits where the technology itself serves only to hide the essence which it is trying to reveal.

The art installation allows us to be critical of technology, to look into the soul of technology and be aware of its potential danger. Yet, many museums only celebrate the achievements of technology, presenting a view of technology as generally progressive, wholesome, and beneficial. Heidegger's view of technology acts as a useful antidote to museums as propagandists for technology in that it warns that technology has dangers as well as benefits. A central aspect of the Heideggerian scheme is that the success of technology blinds us to its dangers because we can only see technology at its surface level as standing reserve:

> The essential unfolding of technology threatens revealing, threatens it with the possibility that all revealing will be consumed in ordering and that everything will present itself only in the unconcealment of standing-reserve. Human activity can never directly counter this danger. Human achievement alone can never banish it. But human reflection can ponder the fact that all saving power

> must be of a higher essence than what is endangered, though at the same time kindred to it. (Hein, 1990, p. 170)

This danger has been made all too apparent in a number of well documented cases in which the commercial or political pressures which influence the stakeholders in technology–based museum exhibits or galleries can cause the subject matter to be presented in an uncritical way. The *Enola Gay* exhibition held in 1994 at the United States National Air and Space Museum in Washington created considerable controversy (Molella & Stephens, 1996, p. 96). The controversy stemmed from the fact that its subject matter, the airplane that dropped the atomic bomb on Hiroshima, was presented in such a way that it offensive to veterans groups who saw the exhibition as pro-Japanese. The resulting debate “only quieted down when the Smithsonian agreed to present the plane essentially without context” (Hein, 1990). In the United Kingdom a rather more muted discussion has surrounded the *Food for Thought* exhibition at the National Museum of Science and Industry in London. This exhibition, sponsored by the food retailer Sainsbury’s, emphasized “the technical rather than the economic, the social, or even the political aspects in the display of food production” (Macdonald & Silverstone, 1992, p. 79). The London Science Museum has avoided becoming involved in the significant debates about food safety current in the United Kingdom by presenting the technology of food production in a partly decontextualized and uncontroversial manner.

Both these cases serve to underline Heidegger’s central thesis which is that technology carries with it both danger and salvation. If we remain fixated by technology alone, then we can never progress to understand the essence of technology—it remains forever concealed. Heidegger viewed danger and salvation as being two sides of the same coin. As we progress towards an understanding of the essence of technology, we progress towards an understanding of the means of our own salvation from the danger of technology. It is through artistic revelation in *poiesis* that we can begin to understand how we can be saved from it. Heidegger’s essay closes with the words:

> The closer we come to the danger, the more brightly do the ways into the saving power begin to shine and the more questioning we become. For questioning is the piety of thought. (Heidegger, 1978b, p. 341)

This statement is significant because it places the *manner* of our enquiry to the forefront. Questioning is not merely permissible, it is an essential requirement in seeking the truth. Heidegger’s view inevitably carries a moral force because he invests the process of questioning with the religious virtue of piety. The view that the manner of enquiry has an ethical basis has been put forward by Degenhardt (1998), who stressed the importance of questioning for teachers:

> But teachers need to be more scrupulous in helping learners see that the encounter with diversity of beliefs is a starting point in the quest for truth, not a reason to abandon it. (Degenhardt, 1998, p. 342)

Similarly, it is this stress upon questioning which saves Heidegger from the accusation that he is merely propounding a sterile form of essentialism. As with Degenhardt, it is the *manner* of revealing which is important. If truth is to be approached then it needs to be done in a spirit of critical reflection.

Heidegger and Education

Despite being one of the most influential—and controversial—philosophers of the twentieth century, Heidegger is a figure whose work rarely, if ever, is seen to have any bearing upon the philosophy of education. This neglect aside, his writing upon the philosophy of technology does have a significance for those engaged in education. The interactive science and technology center (ISTC) provides a case study in which Heidegger's ideas can be applied. This is an unusual opportunity for philosophical analysis.

Heidegger's attempt to show how the essence of technology is to be approached raises important issues for us all with regard to our understanding of the natural world through science and its transformation through technology. His is one of the first voices to be raised in the twentieth century, not against technology *per se* but against our blindness in appreciating the danger that our love for technology can bring. He is not an intellectual Luddite but rather he is one who sees in the danger of technology the possibility of salvation.

In the specific context of the ISTC, Heidegger's ideas act as an antidote to those who are intent upon presenting an uncritical celebration of the achievements of technology. Of course, this does not mean that we should demonize technology—whether presented in museums, in the classroom, or in the workshop—but rather it means that we must, in Degenhardt's words; engage in "deepening critical reflections" (1998, p. 342). The exhibits found in ISTCs provoke interest in that they represent technological artifacts whose major function is to promote reflection. In these objects we see the processes of challenging, ordering, and revealing reified. Paradoxically these exhibits become the means by which the *visitor* is transformed, the means by which the unfolding of technology is revealed. Poetic or artistic interpretations of technology are significant in that, by cutting through the familiar surface detail which technological artifacts present, these interpretations can help us to approach the essence of technology and, in so doing, make us more aware of our own responsibility in shaping the world. Too few examples of this kind exist. Exhibit designers are as in love with technology as any one else and are just as apt to place the mechanics of an exhibit between the visitor and the essence of technology.

In conclusion, the difficulties associated with Heidegger's writing should not blind us to the fact that he has much to say which is of value particularly as we move into a global society whose culture is increasingly defined by its technology. It is perhaps more relevant now, at the beginning of the 21st century, to take stock of what he had to say at the midpoint of the 20th century.

There are tasks ahead: the first is to make Heidegger's ideas rather more intelligible to the lay mind or at least, by bringing them into the philosophy of education canon, to make them more intelligible to the minds of teachers. This is primarily a task for those in engaged in the pre-service and in-service education of teachers. If the philosophy of education is taught at all, then it needs to be seen as shaping the practice of teachers. Heidegger's ideas call us to reflect critically upon the role and purpose of technology in our lives, it should also be seen as a reason for reassessing the way in which science and technology is presented in schools.

The second task is more immediate in that it relates to the increased emphasis being placed upon science and technology in school curricula around the world. It goes without saying that science and technology will continue to have an undoubted instrumental impact on the success of our modern lives. In the United Kingdom the advent of the National Curriculum has meant that attention is now being paid towards encouraging pupils to reflect upon the nature of *science* and yet no clear strategies exist in schools for encouraging reflection upon the nature of *technology*. Technology has an advantage over science in so far as the school curriculum is concerned in that it shares its roots with the creative activity of the artist: *techne* and *poesis*, according to Heidegger, share a common inheritance. Is it possible that through *poiesis*—our artistic and poetic understanding—something of the essence of technology may be revealed?

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Special Feature

NSF Funded Projects: Perspectives of Project Leaders

Rodney L. Custer, Franzie Loepp, and G. Eugene Martin

The potential for significant grants for technology education in the United States has increased in recent years. In addition to state agencies, federal agencies such as NASA, the National Science Foundation (NSF)[1] and the United States Office of Education (USOE) have begun to fund technology education. Also, private foundations such as the Technical Foundation of America (TFA) and companies such as the AutoDesk Foundation have also issued requests for proposals (RFP) to enhance technology education. This momentum will no doubt continue.

The advocacy for a more technologically literate society is being championed by prestigious agencies, organizations, and associations. For example, the NSF and NASA have not only funded the development of *Technology for All Americans: A Rationale and Structure for the Study of Technology* (1996), but also the development of K-12 content standards for technology education which were released in April 2000. The National Academy of Sciences (NAS), the National Academy of Engineering (NAE), and the National Research Council (NRC) have launched initiatives to make the case for technological literacy for all Americans. Furthermore, the American Association for the Advancement of Science's *Benchmarks* (1993) and the NRC's National Science Education Standards (1996) both contain sections focused directly on technological literacy.

It is important to note that all of these agencies have been involved in the development of standards for technology education (International Technology Education Association, 2000). NASA and NSF have provided major financial support and the NAS, NAE and NRC have assembled committees to review the standards and make recommendations. It is therefore anticipated that the development of instructional materials and teacher enhancement programs will have funding priority now that the standards are published.

Should this prediction come to fruition, it is extremely important for leaders in technology education to proactively respond to requests for proposals. The record shows that a few technology educators, a few science educators, and a

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few engineers have been responding to RFPs related to technology education. With the trend toward increased funding opportunities, it is imperative that this record be improved. Herein is the problem.

Statement of the Problem

The technology education profession in the U. S. is being presented with a significant opportunity to participate in NSF-funded programs. The presence of technology educators on the staff of NSF and the growing number of funded technology education-related proposals (including the ITEA's *Technology for All Americans* standards project) are among the factors that increased the visibility of technology education at the NSF. Increasingly, technology education is being valued at NSF, not only on its own merits, but for its promise for integrating content from across the disciplines and for helping mathematics and science educators deliver their content in an inquiry-based manner.

The opportunity exists for creative, energetic technology educators to develop instructional materials, enhance teachers, and conduct research. New program announcements will have opportunities for educating all teachers in science, mathematics and technology. And there will be more opportunities to do applied research. For example, an excellent research topic would be to determine the impact "design" has on student learning. More research needs to be done on the enhancement of teachers so as to promote student learning. To pursue these avenues of research, one might check the Division of Research, Evaluation and Communication at the NSF, which has a new emphasis on Research in Learning and Education (ROLE). For resources to develop K-12 curricula or to enhance teachers, contact the Elementary, Secondary, and Informal Education (ESIE) Division.

While the opportunities expand, the challenges also increase. For example, over the past decade, the number of faculty in technology education teacher education programs has declined. This is particularly true in research oriented programs, where grant proposal writing and publications are valued and rewarded in the tenure, promotion, and merit structures. Another problem is that the grant writing process for federal funding is extremely demanding and the standards are high. In order to achieve success in this arena, technology education faculty are being required to learn new skills and to expand their awareness of the potential for innovation and creative activities. Many faculty feel torn between launching into these creative new opportunities while, at the same time, meeting the escalating demands associated with shrinking numbers of faculty doing the work of the profession. Others worry that they lack the skills and background needed to compete successfully in federally funded program initiatives.

Moreover, faculty are also discovering that it is necessary to expand their range of contacts to collaborate with faculty from other academic areas if they are to succeed in the competitive grant writing arena. As a profession, technology educators are being encouraged to expand their circle of professional acquaintances beyond the profession to the larger educational community (particularly with science and mathematics educators). It takes considerable time and effort to nurture these relationships and to develop mutual respect and trust. Often, these new alliances require serious and even painful rethinking of content, pedagogy, and political structures.

The technology education profession is at a critical juncture. The level of opportunity for participation in NSF and other funding agency possibilities has never been better. At the same time and for a variety of reasons, the level of participation and involvement of technology educators in these programs remains relatively low. A gap exists between a new openness to the profession (by the NSF) and technology educators' level of participation and inclination to respond. Who will fill this void?

Purpose and Research Objectives

The purpose of this study was to examine the perceptions and experiences of individuals who are currently being funded by the NSF to conduct a variety of technology education-related projects. These projects are of three major types: instructional materials development, teacher enhancement, and technician level program enhancement. The latter is focused primarily at the community college level. The study was conducted in the context of two Principal Investigator (PI) meetings, which were designed to facilitate the exchange of ideas and information among project leaders.

The objectives that provided focus for this study were to:

1. Explore perceptions of PIs regarding significant barriers and hurdles faced by those pursuing funding by the NSF for technology education-related programs,
2. Explore PIs' perceptions on a range of issues related to NSF program participation (e.g., problems in working with publishers, strategies for sustaining projects beyond funding, ways to overcome implementation barriers, addressing national standards, assessment challenges, etc.),
3. Obtain ideas and suggestions about how more professionals could be encouraged to participate in grant writing opportunities.

Methodology

At the 1998 International Technology Education Association (ITEA) conference, Drs. Dan Householder and Gerhard Salinger (NSF Program Officers) convened a group of approximately 20 principal investigators (PIs) of NSF funded projects to discuss common issues. The interest of the PIs in such a meeting was high and the meeting originally scheduled for two hours lasted four hours. After the meeting concluded, several PIs met to plan a strategy for obtaining funding and conducting a conference specifically for PIs whose NSF-funded projects related to technology education. Dr. Franzie Loepp of Illinois State University, conference organizer, coordinated the development of a proposal to plan and conduct the conference.

It was noted that PIs with projects in Advanced Technological Education (ATE)[2] and science and mathematics already held annual conferences. These conferences provided a model for the PI Conference for NSF Projects Related to Technology Education that was held in Washington, DC, on November 18 and

19, 1998. Because of the close relationship between technology education and ATE, it was decided to have the conference at the same location as the ATE PI Conference that was held immediately following the conference for technology education. An invitation was extended to all the technology education PIs to attend the ATE conference as well.

Sample and Procedures

The data for this study were gathered in conjunction with a formal evaluation of the PI conference, held in Washington, DC, in conjunction with the ATE conference. At the close of the conference, participants were provided an orientation to the research study and were formally asked to participate. Survey instruments were distributed to 37 PIs in attendance at the conference and verbal instructions were provided by the evaluator. Participants were asked to return their completed instruments within two weeks. Following this two-week period, follow up letters, a second copy of the instrument, and email messages were sent to non-respondents. After a second two-week response period, a second reminder was sent to remaining non-respondents. These procedures generated a total of 23 usable instruments, for a return of 62.2%.

Instrumentation

The instrumentation used in this study was a five-page, 18-question survey developed by the authors. It was comprised of three major sections. The first section requested demographic information such as type of program, number of previously funded NSF projects, number of proposals submitted to NSF, and so forth. The second section included six open-ended questions designed to explore the perceptions of PIs regarding issues such as barriers to participation, helpful suggestions and assistance received, advice to the NSF, etc. The third section was a series of questions using a five point, Likert-type rating scale with additional space for elaboration. This last section of the instrument was designed to probe the participants' perceived level of understanding of a variety of project related issues and topics (e.g., constructivism, inquiry-based curricula, standards, etc.).

The initial draft of the instrument was developed by the authors and was based on the objectives identified in the PI conference proposal submitted to the NSF and the objectives established for this study. The initial draft was then submitted to a panel of three experts who were intimately familiar with NSF-funded programs as well as program assessment issues. The panel critiqued the instrument and made suggestions for improvement. After the instrument was revised to address the panel's recommendations, it was resubmitted to the panel for a second review. Through this process, a number of substantiative changes were made to the instrument and all of the concerns and suggestions of the panelists were either incorporated into the instrument or resolved in consultation with individual panelists.

Data Tabulation Procedures

Two types of data were generated by the instrument. Responses to the Likert-type scale questions were tabulated and descriptive statistics (means and standard deviations) were calculated. For the open-ended response questions, all raw data were entered into a database (Microsoftä Access). After the accuracy of these transcriptions had been determined, the authors independently analyzed the response set for conceptual themes for each survey question. These separate lists were developed and then they were compared, discussed, and merged into a single set of response themes. One set of response themes was developed for every open-ended question on the survey.

After the set of response themes was developed, the authors independently organized each response item into one of the response theme categories. This provided a mechanism for tabulating the frequency of identical (or closely related) responses. For example, one response theme generated for the "hurdles encountered when developing NSF proposals" question had to do with understanding and meeting NSF's expectations. Three individuals responded with comments indicating that this had been a significant hurdle in their experience with NSF. After the responses had been independently organized into themes, the categorizations were compared and differences were discussed and reconciled by the researchers.

To enhance the potential for the results of the conference to have depth and meaning, a qualitative component was added to the data collection process. One of the authors who is familiar with funded projects and a recognized process observer, served as rapporteur. His role was to actively listen to presentations and discussions throughout the conference and then make reflective comments during the last conference session. Following the conference, these comments and some additional reflective materials were formally submitted in written form to the conference organizer and the external evaluator.

Findings and Discussion

The first set of questions focused on the participants' perceptions of the kinds of experiences that had proved either beneficial or problematic as they pursued funding through NSF. It is important to note that the sample was comprised of those who have been funded by NSF. As such, their perceptions could differ from those who were not funded.

When participants were asked to identify the factors that had been most helpful to them throughout the process of writing a proposal and receiving funds from NSF, the single most important item was direct interaction and contact with NSF Program Officers (see Table 1). Most of the responses were even more detailed, extending appreciation to NSF program officers by name, for example. This is important information, because the perception persists that it may be inappropriate or even unwise to contact Program Officers. In reality, the NSF encourages interaction between potential grant writers and NSF personnel, because such interaction provides an opportunity to share and explore the viability of project ideas and strategies. It also provides a means for clarifying program guidelines.

Another mechanism for increasing the flow of communication between NSF and potential grant writers is through NSF's "rotator" program. Many of NSF Program Officers serve as rotators, typically for a period of 1-3 years. These

Table 1
Suggestions That Were Most Helpful in Obtaining Initial NSF Funding

Category	*f*
Interact with NSF Program Officer(s)	12
Write a clear, well-organized, direct proposal	4
Collaborate with successful PIs	4
Follow recommendations of reviewers	3
Obtain services of a qualified external evaluator	2
Review funded proposals	1
Review program guidelines carefully while writing proposal	1

individuals are usually faculty from colleges and universities, or come from funded research agencies or the private sector. Among the responsibilities of rotators (as well as full time NSF staff) while at NSF are constituting and conducting proposal review panel meetings, negotiating grants, conducting site visits, and interacting with grant writers. This practice of integrating temporary staff as active participants into the NSF decision-making process is valuable in several important ways. First, it provides a mechanism for better informing potential grant writers (i.e., rotators) about NSF guidelines, the processes used, and available funding opportunities. When they return to their home institutions, they are equipped to serve as valuable sources of information about NSF programs. The practice also serves to keep a steady flow of new ideas to NSF and to maintain contacts within the organization. In addition to new concept ideas, each new rotator comes to the position with colleagues and contacts who are qualified to serve on proposal review panels. They also know people who should be encouraged to write proposals.

Thus, interaction between potential grant writers and NSF is strongly encouraged and facilitated. Contacts typically include participation on grant review panels, phone calls and visits to NSF headquarters, and service at the NSF. This collaboration and interaction theme is further emphasized in the remaining categories presented in Table 1. In addition to interacting with program officers, respondents noted the value of collaborating with other successful PIs and following recommendations of reviewers.

Two of the items in Table 1 received only one response. One was the review of program guidelines and the other the review of successful project proposals. This was surprising to the authors since NSF considers familiarity with these documents to be important sources of information for successful grant writers. The results of this study indicate that this sample of successful grant writers found direct personal contact with knowledgeable individuals to be of more value than information obtained from NSF documents. While program guidelines are important and essential tools for communicating program information, assistance from persons experienced in reviewing, funding, and obtaining grants is needed in order to interpret the guidelines. Interpreting program guidelines is frequently a daunting experience, particularly for those who are new to the grant writing experience.

The sample also identified some barriers encountered by the PIs during the grant writing process. This issue was addressed from two slightly different perspectives. First, the PIs identified the hurdles they had faced when developing their NSF proposal (see Table 2). From a slightly different perspective, they were also asked to discuss barriers that they believe discourage potential grant writers in areas related to technology education from submitting to NSF's programs (see Table 3).

Table 2
Hurdles encountered during proposal development

Category	*f*
Conceptualizing and visioning the project	8
Getting collaborators to follow through with commitments	4
Getting home institutions to accommodate needed changes	4
Developing the budget	4
Understanding NSF guidelines and expectations	4
No significant hurdles	4
Understanding and responding to reviewer comments	2

Table 3
Barriers that Discourage Technology Education-related Grant Writers from Developing NSF Proposals

Category	*f*
Lack of time to develop and implement grants	6
Lack of self-confidence with grant writing	5
Complexity of the guidelines and the process	5
Perception that competition will make funding unlikely	4
Obtaining good grant writing assistance	4
Lack of experience in grant writing	3
Lack of support with dissemination	1

The most frequently noted hurdle was conceptualizing and envisioning projects. This is an important point. Responding to program guidelines is much more complex than simply following straightforward formulas. Most NSF program guidelines are broadly written, systemically oriented, and designed to encourage creative approaches to complex problems. As such, the conceptual demands may be much greater than grant proposals written to agencies and organizations where the guidelines are more narrowly focused and prescriptive. A key recommendation frequently given to potential NSF grant writers is to begin with a good idea. If the idea is good, then it can be refined. As indicated previously, developing, testing, and refining project ideas is a creative and demanding process that requires collaboration, familiarity with numerous projects, understanding program guidelines, learning how to write good proposals, and more.

Management issues were a second type of hurdle identified. Specifically, grant writers noted the challenges associated with working with collaborators and personnel at their home institutions. These are real problems. The systemic nature of many NSF programs strongly encourages collaboration among and across institutions and programs. Through this process, partnerships and alliances are often forged among players who know relatively little about one another and who frequently are working together for the first time. The process is exacerbated by the fact that those actively involved in funded projects tend to be busy people, who are attempting to balance the demands of teaching and research with heavy workloads on multiple projects.

Collaboration is strongly encouraged and, in some cases, mandated by program guidelines, due to the potential for synergy and systemic impact. At the same time, it is also very important for potential collaborators to engage in the hard work needed to get to know what each person can contribute to the project, understand the constraints within which they will be working, and know the personal and professional characteristics (e.g., follow through, work style, reputation, expertise, etc.) of their potential collaborators. Individuals who tend to be most successful with collaborative relationships in funded projects are those who have been active with professional organizations and project work for long periods of time. They are well connected and have developed a network of contacts that can be engaged in work that is of mutual interest and which engages the expertise and imagination of everyone involved. Collaboration is critically important, but it also involves additional work and sound judgment.

The issues involved in working within the constraints of the variety of institutions within which researchers work can also be problematic. Institutions have different cultures and organizational structures. They follow different sets of rules and constraints. Some are academic while others are governmental or in the private sector. One of the hard realities of writing and implementing grants has to do with being able to forge an alignment among program guidelines, creative and innovative project ideas, and the unique (and often conflicting) regulations and constraints imposed by institutions. Bringing these into alignment is often one of the more frustrating challenges involved in project implementation. It is important to develop and maintain good working relationships with key officials with the institution. Experienced people who "know the ropes" are generally available within most institutions. They are of immense value when it comes to navigating the myriad of details and problems that can impede, or even ruin a project.

The participants also identified the difficulties associated with developing budgets and understanding program guidelines. Again, the importance of collaboration cannot be overstated. Often, those whose expertise is in conceptualizing projects, motivating partners, and providing leadership may know relatively little about budget detail. If funded projects are to be successful, it is essential that the expertise of many different people be engaged. This includes PIs, Program Officers, grant writers, budget officers, and others.

As noted earlier, this is a time of tremendous opportunity for the Technology Education community. NSF and other funding agencies are encouraging technology educators to respond to RFPs and to become actively involved in grants and projects. At this juncture, however, the level of opportunity far exceeds the response from technology educators. One of the questions in this study focused on gaining some insight into this issue (see Table 3).

The barriers identified by the sample can be broadly classified as external (i.e., time, resources, assistance, etc.) and internal (i.e., self-confidence, concern with lack of experience, etc.). Those who are active with funded projects are quite familiar with both types of barriers.

External Barriers

The problem of time is real. In technology education, the numbers of teacher educators and teacher education institutions are shrinking. Some of the remaining programs are doing extremely well, with dramatic growth in enrollments, new faculty lines, and increased levels of funding. Other programs are working hard to build and rebuild programs. In both cases, time and energy demands on faculty are very heavy. For example, it is not uncommon for faculty to teach 3-4 courses per semester, while supervising student teachers, and attempting to pursue an active publishing and research agenda. Now that the *Standards for Technological Literacy: Content for the Study of Technology* has been published, there will be new opportunities (and expectations) for leadership in the curriculum development area.

Given these kinds of demands, unfortunately, many technology teacher educators are reluctant to pursue funded projects. The time and energy demands are perceived to be too great. Fortunately, colleges and universities also value external funding. In fact, pursuing external funding is increasingly becoming an integral part of the expectation of faculty across higher education. While time constraints are real, reward structures increasingly are encouraging grant writing involvement, with opportunities for being released from regular job duties, merit recognition, and salary increases. As technology educators, we are extremely fortunate that the escalating expectations for involvement in grant writing coincide with strong encouragement and opportunity from a variety of funding agencies.

Internal Barriers

Another barrier commonly experienced particularly by individuals new to grant writing is self-confidence. The perceived level of competition for grants, complexity of the program guidelines, and expertise of successful project leaders lead prospective grant writers to conclude that they are ill-equipped for the task. These are valid perceptions. Grant writing for NSF and other major funding agencies is highly competitive. It represents new and intimidating territory for many technology educators. However, most assuredly, these feelings are not unique to technology educators. Most new grant writers from all academic backgrounds and experience are not very confident about their ability to succeed. Even experienced grant writers struggle, often seriously, with the challenges associated with conceptualizing, writing, and implementing projects. Virtually no one is successful with every grant proposal. Those who are successful are generally those who persist. Successful grant persons carefully attend to the reviews received from unsuccessful proposals. They demonstrate a willingness to reach out for support and assistance, and have the courage to try again, often repeatedly.

One issue that should be addressed in this context is the perception that funding agencies prefer to fund experienced people and that "first-timers" are at a disadvantage. There may be elements of truth in this perception since good grant proposal writing is an acquired skill and it is a function of experience. Those who have been successful are advantaged by having more and different kinds of contacts and experiences. Funding agencies also need to have confidence in the ability of project leaders to successfully implement ideas and manage the project. Thus, in this way, experienced grant writers do have some competitive advantage.

At the same time, we know from our experience with NSF and other funding agencies that there is strong interest in encouraging and equipping new participants to submit grants. Various mechanisms are used to provide assistance. Most programs require pre-proposals, which are brief concept papers that provide an opportunity to outline a project idea in a relatively brief format. Program officers (and in some cases, even full panels) provide feedback about the potential of project ideas as well as useful suggestions for how to best write a full proposal. As noted earlier, program officers routinely meet to discuss project ideas with potential grant writers and welcome opportunities to interact with a variety of people on project ideas. University research offices and successful PIs may serve as valuable resources for encouraging and providing assistance to faculty who are inexperienced with writing grants.

Technology educators should know that they are as equally well-equipped to participate in successful grant writing as are professionals from other academic areas. With the development of the *Standards for Technological Literacy* and their endorsement by the National Research Council and the National Academy of Engineering, there is strong interest at NSF and other funding agencies to increase the level of involvement of technology educators as key players in the broader educational enterprise. From this perspective, it could be argued that technology educators are in a period where they may hold a competitive advantage.

The concerns about experience are real barriers to participation. Problems with time, energy, and other resources are real also. In fact, one of the insightful observations made by the conference rapporteur, was that these challenges are not unique to new grant writers. "They exhibited varying levels of frustration, openly talking about their own insecurity and the future of their NSF projects" (Martin, 1998). But, these challenges can be overcome, and the assistance and rewards are there for those who are willing to engage and persist.

Participants were also asked to identify the benefits they had experienced as a result of working with NSF-funded projects. As can be seen in Table 4, the single most important factor was being able to engage in significant and meaningful work. Comments included, "the opportunity to make a difference in education," "being an active participant in educational reform," and "chipping away at changing the ways in which we help students learn."

Table 4
Reasons to write NSF Proposals

Category	*f*
Provides the resources to do something significant	14
Brings recognition and credibility to institutions, programs and individuals	3
Promotes collaboration, organization, and support	2
Stimulates personal and professional growth	2
Curriculum development	1
Do not recommend NSF – too discipline specific	1

As noted in the methodology section, the data gathering process also included a qualitative component, whereby a rapporteur carefully observed the conference, interacted with the external evaluator to share observations and perceptions, and then formulated a set of observations. One key component of this report included a description of the characteristics of respondents, which are particularly pertinent to this discussion of why people choose to participate in funded projects. The observations of the rapporteur on successful NSF grant writers are:

1. They are quite cognizant of their sense of purpose as to why they originally applied for a NSF award and what they want to accomplish with their award. There are no gray areas in what they want to do and why they are doing it.
2. Through their NSF funded projects, they are very much interested in enriching the lives of others.
3. They are energetic to initiate their projects and carry them through to completion and they are excited about what they are doing and the impact they could have on students.
4. The ideas for their projects did not just happen by chance. The investigators are inquisitive about what they are personally doing with their research and what others are doing with their funded projects. They are deeply interested in knowing what others think about their efforts. They are caring individuals.
5. They are interested in sharing information about their projects. Sharing appears to occur from the moment the project is approved by NSF until the project is completed. Their sharing attitude comes about as a result of the recognition and value they place on the work and worth of others.
6. They are innovators and risk takers. They are willing to try what may at first seem like "silly" ideas to many and bring the ideas to fruition. Because they are innovators and risk takers, they probably tend to stand out among their peers. As risk takers, they are also futuristic. They are

willing to invest time and energy now for a better tomorrow. Thus, they are also patient and impatient.

7. They want to be part of and play a significant role in the synergy that is occurring in advancing the cause for technological literacy for all Americans.
8. As a result of the knowledge they have developed through their funded projects, they want recognition and this recognition appears to be in the form of being recognized by their peers as experts in their field of knowledge.
9. They are not complacent. Award winners want to make things happen and they want the things to happen now.
10. They are willing to accept failure in what they are doing. At the same time, failure becomes a challenge to try something new or in a different way.
11. They are a focused group. They are not obsessed with manipulative activities, student competitions, or positioning their disciplines. Instead, they are clearly focused on a better understanding of how students learn.
12. They openly discuss with self-confidence the relationships among math, science, and technology.
13. They are so confident in what they are doing that they have the audacity to believe that they can really make a difference. (Martin, 1998).

In summary, the benefits are clearly evident for professionals who possess or are able to develop certain kinds of characteristics. Among these characteristics are an ability to envision change and believe in the capacity for making a significant difference. They typically possess high energy, an ability to focus and sustain work over time, and an ability to collaborate successfully with many different people and constituencies. Individuals who possess these kinds of characteristics tend to be involved with funded projects. They are also the kinds of people who tend to experience the joys and benefits of that type of work.

Conclusions and Recommendations

As future funding topics are considered, the following may serve as food for thought for the generation of new and exciting projects.

1. The PI conference that was the basis for this study provided a means for sharing information and celebrating the successes of award winners. While this kind of interaction is valuable, it would be useful to find ways of extending this opportunity to a wider circle of professionals, including potential PIs. This would serve a valuable orientation/training function. It would also be a way of disseminating information about the kinds of excellent projects that are currently being funded. One idea would be to arrange for this type of conference at the major conferences of the math, science, and technology disciplines.
2. While the participants in this study were primarily teacher educators, it is important to remember that teachers and students are ultimately the primary stakeholders in the educational reform process. The NSF requires the involvement of elementary and/or secondary teachers in

Instructional Materials Development (IMD) and Advanced Technological Education (ATE) projects. Teacher enhancement should be directed at all levels within the technology education profession.

3. The "traditional" technology education population needs to expand the circle of groups and individuals with which it interacts and engages. The attendees at this conference provide ample evidence that technology education is much bigger than what the traditional community might think. The synergy generated across disciplinary boundaries should be encouraged.
4. Completed NSF projects need to be critiqued by objective and disinterested parties. Those projects that are deemed worthy should be disseminated to a larger audience as part of the annual grant program.
5. There was much discussion of the type of teachers needed to make change happen within the profession. Some of the presenters talked about the need for integrators while others identified the need for people who could manage chaos and who were facilitators. Much work needs to be done in identifying specific characteristics of teachers needed for the 21st century. Procedures also need to be developed for identifying, equipping, and encouraging individuals to respond to NSF and other grant writing opportunities.
6. A concerted effort should be made to monitor the requests for proposals distributed by the NSF (http://www.nsf.gov/), Department of Education (http://www.ed.gov/), NASA (http://www.nasa.gov/), and private foundations. Mechanisms should be developed to better disseminate this kind of information out to the technology education community.
7. The problem with low self-confidence in grant writing needs to be addressed. This can be done in a number of ways, including establishing mentoring relationships between successful PIs and high talent potential project leaders, encouraging participation at PI conferences and other grant-related information sharing and training activities, to name a few. On a larger scale, creative ways should be explored to build consortia whereby professionals can be encouraged to collaborate with others, build a creative vision, establish progressive goals, and foster sound strategies for proposal development.
8. Those interested in writing grant proposals should be encouraged to interact with program officers, PIs of funded projects, and other knowledgeable individuals.

Notes

[1]The National Science Foundation (NSF) is an independent agency of the U.S. Government with a mission "to promote the progress of science; the advancement of the national health, prosperity, and welfare; and to secure the national defense." NSF funds diverse projects, ranging from basic scientific research to a variety of educational initiatives. Additional information on the NSF and its programs can be found at http://www.nsf.gov.

[2]The focus of the ATE program is on enhancing the nation's "high tech" workforce at the two-year college level, particularly related to science, mathematics, engineering, and technology.

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Editorial

Technology Education Research: Potential Directions

Fernando Cajas

Current educational reform proposals recognize the importance of understanding technology and have identified certain technological abilities as goals for all students. Important examples are the *Benchmarks for Science Literacy* of Project 2061 of the American Association for the Advancement of Science (AAAS, 1993) and the *Standards for Technological Literacy* of the International Technology Education Association (ITEA, 2000)[1]. In the international arena the United Nations Educational, Scientific and Cultural Organization (UNESCO) has also recognized the urgency of technology literacy throughout its *Innovations in Science and Technology Education* series.

The above reform movements call for understanding concepts and principles of technology such as design, control, and systems and also some important ideas about technology in specific areas such as materials, energy, and communication (AAAS, 1990; ITEA, 2000). In doing so they are transforming the field of technology education, within a context of literacy, asking for a deeper understanding of the nature of technology. This transformation has important implications for any potential research agenda for technology education.

Project 2061 of the American Association for the Advancement of Science (AAAS) held a conference to consider what kind of research would enhance the goal of achieving universal technological literacy. Last December, thirty-five participants from science education, technology education, and cognitive science convened to discuss the role of research in technology education. Technology was discussed from a wide perspective, including the relationship between science and technology, the notion of design, control mechanisms, materials, energy, and communication. The overall goals of the conference were to raise consciousness on the needed research and to begin a discussion for a research agenda in technology education.

The American Association for the Advancement of Science has long recognized the importance of technological studies in the education of all Americans. Since 1985 Project 2061 has been promoting literacy in science, technology, and mathematics ("science literacy" for brevity). In *Science for All*

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Americans, Project 2061 recommended ideas and skills for adult science literacy. *Benchmarks for Science Literacy* suggested specific attainments in grades K-12 along the way toward science literacy. In thinking about students' developmental patterns, the Project 2061 staff has long felt the need for research on how students learn specific ideas and skills, particularly in the study of technology. Therefore we want to encourage research on when and how students can achieve specific literacy goals (AAAS, 1998). This conference called for an evaluation of the role of research in technology education in promoting technological literacy.

Origins of the Conference

In early 1999, Gary Benenson, Professor of Mechanical Engineering, City College, NY, and Fernando Cajas, Researcher, American Association for the Advancement Science/Project 2061, established an on-going dialogue about the importance of technology education research. In developing curriculum materials, Benenson and his team have felt the need for research in technology education to guide their work. This feeling is shared by other technology education projects funded by the National Science Foundation (NSF). In Project 2061 the situation is similar. There is a need for good research in technology education to shed light on how students' understanding and abilities grow over time.

The conversation about research in technology education was expanded to a group of technology educators who became members of the planning committee for this conference[2]. The committee met in Washington, DC, to develop a preliminary agenda. The two main issues discussed in this meeting were:

1. Developing a research agenda that can support technology education for all.
2. Setting priorities for research in technology education.

The invitation for the planning committee included the following specific issues and particular research questions:

- What steps could be taken to make a case for technology education in the K-12 curriculum?
- What are the core concepts in technology education?
- Should integration with other subjects (e.g., science courses) be a priority for technology education?
- Who are the technology education teachers and who are the students?
- How do children learn technological concepts (e.g., design under constraint)?
- What kind of research is needed to support the creation of good curriculum materials to teach the big ideas and skills in technology education?

The Conference: A First Glance

The conference was framed around four issues: Research Areas, How Children Learn Technological Ideas, Research Methods, and Assessment.

From the beginning, the conference produced meaningful discussions. After an opening technology activity (Benenson) and during a presentation on how technological ideas and skills might progress from K to 12 (Soren Wheeler, AAAS/Project 2061), participants engaged in an intense discussion about the difficulties of teaching ideas of systems. Discussions highlighted the tension between knowing and doing in technology education which is related to the important distinction between knowing about technology and doing technology. The knowing/doing theme was part of many other discussions in the conference and was linked to the need for research about effective ways to learn technology.

The issue of "Research Areas" was addressed in several presentations and discussions. Robert McCormick (Open University, UK) suggested specific areas of research such as the distinction between procedural and conceptual knowledge in technology education. Using the context of mapping technological ideas, Soren Wheeler (AAAS/Project 2061) called for developing a picture of the progress of understanding of technological ideas and skills from grades K to 12 and the need for cognitive research that explains how students develop this understanding. Karen Zuga (Ohio State) suggested that there may be cultural differences in how students learn and what they know about technology. But we still do not know what children learn about technology. Although Zuga and W. Tad Foster (Indiana State University) presented an account of the kind of research that has been done in technology education, this research has not explored what children are learning about technology.

The second issue, "How Children Learn Technological Ideas," was addressed by McCormick's and Patricia Rowell's (University of Alberta, Canada) research about how students learn. Participants and presenters also spent time on "Research Methods" and "Assessment." Theodore Lewis, professor at the University of Minnesota and currently at NSF, and Karen Zuga called for methods in technology education research that depart from the traditional quantitative approach. Janet Kolodner (Georgia Tech) called for more attention to asking the right research questions and using "design experiments" to better understand students' learning. Kolodner's presentation connected the "Research Areas" and "Research Methods" issues. According to Kolodner, research methods should include clinical interviews, discourse analysis, and ethnographies of classrooms.

"Assessment" was addressed in nearly all of the presentations and discussions. Rowell presented her on-going research on how to assess students' understanding of technological tasks and presented data from several case studies that showed knowledge gain. Edward Goldman, a high school teacher from Brooklyn Technical High School, NY, and Dorothy Bennett, an evaluator from Education Development Center, Inc. (NY) reviewed the difficulties of assessing students' understanding of specific technological ideas. For example, they discussed the problems of assessing students' consideration of trade-offs in designing a chair. They used some samples of students' work and discussed the limitations of focusing only on the final product designed. On several occasions, Bennett and Goldman stressed the importance of the collaboration between teachers and researchers.

Reflections

After the conference, participants where invited to reflect on the issues discussed. Several participants shared their thoughts in writing. The reflections focused on whether or not the conference changed or inspired the participants' thinking about research in technology education and what specific next steps need to be taken to focus a potential research agenda for technology education. Each reflection presents thoughts, concerns, and inspirations concerning research addressing technological literacy, with implications for K-12 technology education. These reflections provide a basis for further dialogue and focused research efforts.

What follows is a description of the reflection papers that were presented after the conference. Several papers provide a good description of what happened in the conference (B. Valesey, ITEA). Other papers provide some general directions for research in technology education (R. McCormick). And all of them raise critical issues for thinking about research agendas in technology education. The reflections provide suggestions for needed research, such as:

- Priorities need to be set for what to research, how to research, and where and when to research. A productive research agenda should be planned around student learning of key technological ideas (concepts) and skills (processes) identified for literacy (AAAS, 1993; ITEA, 2000).
- There is a need to do research on how well curriculum materials and classroom instruction actually help students to learn specific technological concepts and skills.
- Research in science and mathematics education and cognitive research in general can be used as models, but it is important to recognize that the issues in technology are different from those in science and mathematics. As research in technology education develops, however, technology education researchers should look for ways to work on common issues with researchers in science and mathematics education.
- It is important to study how teachers themselves understand—and come to understand—technology.
- Research needs to be done to determine the most efficient and cost effective ways to conduct professional development of technology educators.
- Educational research methods can vary greatly, e.g., from traditional surveys to design experiments, from multiple choice questions to in-depth interviews. Case studies would be useful to create an adequate basis for later formal research.

Perhaps the most striking feature of the reflections is that several do not set, nor even mention, priorities. There is a tendency to suggest areas of research without providing a rationale about why one should be prioritized over another. The only exception to this was the reflection by Senta Raizen (The National Center for Improving Science Education). Pam Newberry (ITEA) reminded us about the importance of priorities, stating that, "Time is an issue not just for the school curriculum, but also for planning and developing a research agenda…." We not only have to clarify the areas of research, but also need to provide an argument for which area is most urgent. This is a difficult task, but setting priorities should be a priority itself. For instance, Dorothy Bennett suggested three core areas for further investigation in technology education: Technology Teaching Pedagogy, Student Learning, and Teacher Development. How should we prioritize Bennett's areas of research? If we agree with Andrew Ahlgren (AAAS/Project 2061) that "…student learning is by far the highest priority to study," we may want to consider the following framework:

1. Specific goals for knowledge and skills students will learn.
2. How students learn those ideas and skills.
3. Shaping instruction to promote student learning.
4. Enabling teachers to teach that way effectively.

This priority has a clear rationale: until we learn more about what we want students to learn, what students know and how they learn it, we are not prepared to study instructional methods. And until we learn more about what kinds of instruction are effective, we are not prepared to teach teachers how to do it.

Specific Goals for Learning

For several participants, the question of what everybody should learn in technology education is not problematic. They are aware of how technology ideas and skills have been introduced in current curriculum-reform documents. Franzie Loepp (Illinois State University) and Foster looked to how the new *Standards for Technological Literacy* (ITEA, 2000) are affecting potential areas of research. Other participants pointed to the high priority for determining what specific ideas and skills students should be learning. In pointing out what students should learn about design, Kolodner suggested:

> This requires going back to the design cognition literature and seeing what it says about designing (i.e., identify the practices of expert designers that we might want students to learn). Then asking what, of those skills and concepts, we want students to be learning. Then going to the developmental literature and looking at what it is they might be able learn at certain times in order to build up to this thing you want to get to.

This is an admirably rational plan, which has been implemented during the past decade by at least three institutions: The American Association for the Advancement of Science, the National Research Council, and the ITEA. In the case of AAAS's Project 2061, hundreds of scientists, mathematicians, engineers, physicians, philosophers, historians, and educators collaborated over three years in writing reports that were the basis for *Science for All Americans*, which includes literacy in technology and mathematics as well as in natural and social sciences. There is also a specific Project 2061 report on Technology Education (Johnson, 1989). These reports looked into the nature of technology and design and considered what of that all students should be expected to learn. *Science for All Americans* has at least two full chapters dealing with technology, where specific ideas and skills concerning design, trade-offs, systems, feedback and control, redundancy, and cost/benefit considerations, are clarified. Project 2061's *Benchmarks for Science Literacy* was a second step towards literacy in science, mathematics, and technology based on the best educational research available on what students could learn and when. In *Atlas of Science Literacy* (AAAS, in press), Project 2061 has now taken the recommendations a step further in making maps of how students' understanding would grow from kindergarten to graduation.

National Science Education Standards (National Research Council, 1996) includes some ideas about technology. *Standards for Technological Literacy*: *Content for the Study of Technology* (International Technology Education Association, 2000) is the latest attempt to clarify what everybody should learn about technology. This document appears to have substantial overlap with *Benchmarks*. With the support of the National Academy of Engineering, the technological literacy standards will be a catalyst for the introduction of technology in general education. These documents may need work, but they can be used as a starting point and as necessary common ground.

Despite this consensus on the ideas and skills all students should learn, during the conference there was a spirited discussion about the relationship between knowing and doing in technology education and the effect that this distinction has on what we want students to learn. This tension also shows up in several of the reflections. James LaPorte (Virginia Tech) suggested that "…technology is quite different from science, mathematics, and other core school subjects. The difference is that the essence, the very soul, of technology education is *doing*…. The point here is that a hands-on teaching method is not just a matter of sound pedagogy for technology education. Rather, *doing* (or practice) forms the core of the content of the field."

In regard to the knowing and doing discussion, Kenneth Welty (University of Wisconsin-Stout) laid out a challenging metaphor that examined the difference between an "adventure" and a "journey." An adventure in technology education was characterized as an exciting and potentially rewarding activity that is initiated without any specific intellectual expectations for students. The merits of this approach tend to surface during reflections on the experience. A journey, on the other hand, was described as an activity that has a specific destination in mind. From his perspective, the destination should be the mastery of a profound idea or the development of an essential skill. Welty purports that technology teachers have an affinity for adventures that are launched without sufficient thought about how the student will be different when they are over. With adventures, the attainment of specific goals tends to occur more by default than by design. Technology education will become more valued, he claims, when its activities are designed as journeys toward well-specified outcomes. We believe he respects the value of adventures with technology, but he also values the finite amount of time that is available in the curriculum (even under the best of circumstances).

Thus he believes future research needs to focus on how teachers can best use their precious time to engage young people in journeys (engaging activities) that reach predetermined destinations (the attainment of standards).

How Students Learn

Several participants pointed to specific topics in student learning. McCormick called attention to problems in learning about systems: "Systems knowledge, recognized in *Benchmarks* as conceptual knowledge, is very abstract." This raises the empirical question of how, when, and under what conditions children can learn specific ideas about systems.

There are other problems related to what technological ideas and skills should be a part of technological literacy. Bennett identified central questions in this area. For example: "What types of problem solving strategies do students employ in design problems?" Drawing on his work on problem solving, McCormick reviewed the status of this research in England, where they have found that students follow rigid algorithms reminiscent of the fictional ritual of the scientific method:

> First we often treat design or problem solving as a series of steps. An 'algorithm' notion of design or problem solving characterizes it as consisting of posing the problem and thinking about the problem, clarifying it, thinking of alternate solutions, implementing it, and then evaluating it. This can become a *ritual*…that does not affect the student's thinking.

Despite the research on design and problem solving, we still do not know how children learn specific ideas about design, trade-offs, constraints, redundancy, etc. The work from England may illuminate what we are trying to do in America, but in the U. S. we want students to learn specific ideas about design as well as some basic skills in designing things. In the U. K. there is more emphasis on the "processes," such as the ability to actually design things.

Finally, studying how children learn specific technological ideas and skills will require not just paying attention to research on particular technology topics, but also taking a closer look at the general cognitive research literature. Crismond presented a general overview of the origins of the research tradition of cognitive science and how this experience can help us to think about a research agenda. Hutchinson suggested taking a look at other fields of research as well. We also need to learn from research in science and mathematics education, including its limitations (among others, Ahlgren, Kolodner, and Zuga make this point. See also Schoenfeld, 1999).

Instruction

During the last ten years there have been important developments in the study of teaching, particularly the kind of teaching that current science and mathematics education reforms are advocating (see Lagemann and Shulman, 1999 for a review). This research is helping us to realize that teachers will have to unlearn much of what they believe, know, and do, as Thompson and Zeuli (1999) pointed out:

> The key questions for reform, then, are whether teachers understand that students must think in order to learn and whether they know how to *provoke, stimulate, and support students' thinking*…. That students must think in order

> to learn may seem blatantly obvious. But if it is so obvious, why do so many teachers–in fact, nearly all teachers–fail to see it? (p. 349, italics added)

Science and mathematics education researchers have spent decades dealing with problems of student learning. Researchers in the technology education community need to learn from this. Progress in science and mathematics began only after researchers started asking what science and math ideas and skills students really understood. Then, they moved to developing, on a very modest scale, instructional activities that strongly connected instruction and content. Instructional design was followed by classroom trials, revised, tried again, until students showed successful learning of what was intended. The National Council of Teachers of Mathematics has taken advantage of their research on learning and explored its implications for teaching (for example, the series *Research Ideas for the Classroom,* Jensen, 1993; Owens, 1993; Wilson, 1993). Science education has a similar series *What Research Says to the Science Teacher.*

The situation in technology education is different. Take the example of design. A review of the literature on design indicates that researchers have explored how children design things (Makiya & Rogers,1992), the iterative nature of the design process (McCormick, Murphy, & Hennessy, 1994); and how children's design ideas are related to their technological activities (Fleer, 1999). However, there is almost no research on how children learn about design principles (trade-offs, constraints, redundancy, overdesign, and failure). Research can help in providing information about what ideas students have about design and how these ideas can either help or obstruct their learning. Research would help teachers and curriculum developers to develop instructional activities that guide students' thinking toward these ideas by providing relevant phenomena and useful questions that can motivate, stimulate, and support students.

Many reflections also call for a stronger connection between research and practice, particularly in the classroom (Benenson, McCormick, Rowell, and Valesey pointed out this issue in their reflections). For example, what role should research play in developing curriculum materials such as field testing activities in a classroom setting? Kolodner focused on research questions and methods in the context of developing curriculum materials. She acknowledged the need for several research strategies, including what she called a "design experiment" (Brown, 1992). Assuming that research has to be conducted in complex settings, particularly in the context of curriculum materials development, she called for powerful methods to do research not only on learning, but also on teaching:

> A design experiment bases research in classrooms. Basically, what happens in a design experiment is that you, the researcher, engineer the environment to promote learning. What you do is to take what you know about learning and about practice, and put those together to figure out what you think should be happening in the classroom in order to promote the kinds of learning that you're aiming for…. Design experiments allow you to do research on student

> and/or teacher learning, to analyze the learning environment in ways that lead to useful refinements, and to learn how effective your classroom approach is–all at the same time.

Such an effort requires combining two difficult research areas: one on student learning and the other on teacher learning. The feasibility of this kind of research and where it lies in the hierarchy of priorities need further discussion.

Teacher Development

Loepp called for studying the quality of professional development programs. Meaningful outcomes from such a study, however, depend on an understanding of how teachers learn. Benenson reflects on the need for studying teachers' thinking:

> This conference focused on children's cognitive development. An equally important set of questions has to do with how *teachers* understand and come to understand technology. Research on teachers' conceptual and procedural knowledge should both inform and be pursued in parallel with professional development.

The suggestion is that professional development programs could become a focus for studying how teachers learn to teach specific technology ideas and skills. This kind of work will be impossible without having a solid foundation on how students learn those specific technology concepts and skills. In the mathematics education community, research on and for professional development is just emerging (Greeno et al., 1998). The reason for this recent shift to research on the professional development of teachers is the prerequisite accumulation of knowledge on student learning. It is possible that the technology education community can find a way to speed up its research on student learning, instruction, and professional development, but further discussion is needed.

Concluding Comments

In his reflections about the conference Kenneth Welty pointed out that a common practice in technology education is to engage students in rich activities that are grounded in time-honored practices. He suggested that one new focus for a research agenda would be to study what students are learning from those activities. He also stated that instead of studying current teaching practices in hopes of uncovering content worth learning, our research agenda should focus on how students learn the deep understandings and essential skills for technological literacy. This idea is simple but revolutionary.

The conference and the reflection papers are a small step in the direction of enabling individuals to begin serious dialogues on making progress in research on technology education. However, there were important issues that did not get discussed. In the reflections that Foster wrote, he discussed the limits of time, personnel, and funding available. He argued that a collaborative focus on a small number of high-priority topics was needed. Mark Sanders (Virginia Tech) pointed out the lack of researchers. This is a critical problem for the development of any research agenda. Sanders suggested that this could be overcome by creating an Internet/Web based graduate class to encourage action researchers who might collectively pursue a research problem during the course. Considering the resources and constraints, priorities must be set if progress is to be made.

A second conference on technology education research is being planned. It will be structured around selected issues identified in the first conference. The goal is to stimulate research on students' understanding of specific technological ideas and skills that have been identified for literacy. In framing this conference we will use the proceedings from the first AAAS research in technology education conference and the experience accumulated from other events such as the International Technology Education Association/NSF Forum on Research in Technology Education held in Salt Lake City during the 2000 ITEA Annual Conference. The goal of the second conference is to build on the conversations initiated in the first conference and move toward doing research that can enhance the goal of technological literacy for all students.

Acknowledgments: This article is based on the Introduction to the *Proceedings of the AAAS Technology Education Research Conference*[3]. The author thanks Andrew Ahlgren, Gary Benenson and Carole Thomson and Soren Wheeler for their comments.

Notes

1) The American Association for the Advancement of Science (AAAS, pronounced "Triple-A-S") is the world's largest science organization. Project 2061/AAAS is a long-term science, mathematics, and technology education reform initiative that benefits K-12 students.
2) The conversation was extended to the following individuals: Dan Householder (Iowa State University), Ted Lewis (University of Minnesota, NSF), Franzie Loepp (Illinois State University), Pam Newberry (ITEA), Bridgette Valesey (ITEA), and Ken Welty (University of Wisconsin-Stout).
3) The Proceedings are available through the Website of Project 2061/AAAS: www.project2061.org/technology.

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Miscellany

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