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From the Editor

Mega-Projects, Ticky Tacky, and Our Team

My work in finalizing this issue was immediately preceded by participation in the annual conference of the Technology Education Association of Pennsylvania. This is the fourth time I have attended the event, twice as a "visitor" and twice as a "citizen." I have consistently been impressed with the solid involvement of teachers in this conference, sharing the new ideas they have developed.

This year, one of the keynote speaker slots was filled by a team of teachers from Allentown: Bruce Lubak, Robert Boehmer and Bob Yocum. They have been involved in what they call "mega-projects" for the past several years. A mega-project is a large magnitude undertaking around which students participate. For example, one of the first mega-projects described by Lubak involved the development of a scaled-down, operational roller coaster, modeled after one that was located at a nearby amusement part. Expert advice was obtained from a manager of the park. Eventually, the plans for the roller coaster were obtained from the original manufacturer. Donations of material and other resources were solicited from the community. Hours of problem solving occurred, investigating various materials, processes, mechanisms, and electronic circuits. Once other teachers in the school became aware of what was going on, several wanted to get their students involved. It became a true multidisciplinary effort in which science, mathematics, art, and other subjects within the school were integrated. There was clear potential to involve the entire school.

One of the challenging problems that the students faced was finding a place in which the roller coaster could be assembled without taking available floor space for the ongoing instructional program. Thinking divergently, the students came up with the idea of supporting the unit from the ceiling instead of the floor. Programs to machine various parts of the structure were written for a CNC milling machine and the work began. Well over 1,000 structural pieces were machined from plastic and other materials.

Once the structure was reliably operational, a "grand opening" ceremony was held with members of the community invited, along with the donors who supported the effort. The results were overwhelming. Once the value of what the students were learning became apparent, the flood gates of resources were fully opened in anticipation of future mega-projects. Since the initial effort, additional amusement ride models have been developed, among other projects. An underwater robot was the most recent project, leading to participation in a competition sponsored by NASA. Resources continue to pour in based upon the educational value perceived by the donors. The positive image of the program within the community transferred to the entire school, benefiting everyone.

As I was reflecting about what was being presented, I thought about how much the students were learning and how excited they were, and the elation they felt once the projects became operational. I also thought about how difficult it is, though, to nail down just what students were learning since it varied from student to student and from year to year. Then I thought about curriculum standards and how we typically start with the standards and then develop the instructional activities from them. With mega-projects and other similar endeavors, the teacher does not know what will unfold in terms of learning experiences until the project is underway and even then what the students learn is dynamic, changing day by day. Then I thought about science fair projects and how similar they are with respect to the dynamics of learning compared to the open ended projects we often do in technology education. I also thought about how participation in science fairs is often extracurricular or co-curricular. Then I wondered why this has been the case in the science education community. Is it due to the fact that science fair projects are so open ended that it is impossible to connect them to science curriculum standards? Or is it due to the fact the science teachers have simply not been trained pedagogically to deal effectively with multiple learning activities occurring at the same time, one of the hallmarks of technology education? Or is it simply due to the extensive energy and time that the teacher must devote to engaging students in open-ended projects? Hopefully, we can keep the rope of curriculum standards loose enough to allow our students to be involved in projects like Bruce Lubak and his colleagues have developed. Perhaps each student can have their own personal rope as we guide them down their chosen path of learning, instead of dragging them down exactly the same path.

Thinking about projects caused me to reflect back on the past. It is interesting to me that in the minds of some in our field the notion of a “project” conjures up negative images, harking back to the industrial arts days in which the teacher handed the students the plans for a project that the teacher had chosen and everyone made the same thing. I always find this notion disturbing for there is little in the literature of industrial arts that promoted this type of approach. When I left Montana State University 40 years ago to embark upon a teaching career, under the tutelage of Professor Francis Sprinkle, it was fixed in my mind that having all students do the same project was irresponsible professional practice. I have to admit, though, that I questioned the practicality of this approach during my first year of teaching in Montana when I had an average of 38 students in my classes, in a facility that measured 32 by 32 feet.

Then I thought about some of our current modular curricula and it occurred to me that some of these programs have students doing exactly the same thing—it is just that they do the same thing at different times. Alas, though, it makes it very easy to connect what the students are learning with the curriculum standards, and when we add to it a computerized assessment system it makes for a nice, tidy package that is easy to manage and from which supportive evidence can be generated. The hands-on activities remain, but they can easily become nice-to-haves rather than essential parts of the learning process. The opportunity to apply what they learned through the modules in a capstone *project* may never be reached. The lyrics from an old song, written by Malvina Reynolds, then started to run through my mind:

Little boxes on the hillside,
Little boxes made of ticky-tacky,
Little boxes, little boxes,
Little boxes, all the same.
There's a green one and a pink one
And a blue one and a yellow one
And they're all made out of ticky-tacky
And they all look just the same.

Then I thought about Benjamin Bloom's classical taxonomy of educational objectives (Bloom, 1956) and the level of learning that occurs. The open-ended project clearly rose to the top of his hierarchy, at least in my mind. Then I thought about where students might experience open-ended projects in the other school subjects. I will keep thinking about this, but none has come to mind so far. And yes, here I am again with the "maintain our uniqueness at all costs" caveat again…

What a person considers to be contemporary practice in our field causes me to smile sometimes. While ridiculing past practice and some of the projects that marked eras in our history such as the "birdhouse era," the "pump handle lamp era," and the "cutting board era,"some "do not see their nose in spite of their face." Take for example a project that I like to pick on from time to time—the CO_2 powered race car, aka the Metric 500 Dragster. Could it be that the "Metric 500 Era" is the longest running in our entire history? It started with the Industrial Arts Curriculum Project in the early 70s. It will soon be an activity that spans three generations of students in our programs. On the other hand, one could argue that the design of these cars in technology education programs is analogous to teaching the laws of gravity in science and the classic experiments associated with that teaching—both are essential to the respective disciplines. Perhaps…

If taught correctly, having students design and build the car can be a rich and rewarding experience. On the other hand, the problem is often very tightly constrained. The wheelbase for the car is generally fixed, as is the location of the CO_2 cartridge. In fact, kits are available with the axle holes and cartridge hole predrilled. The students can manipulate the shape within the tight constraints, but do the aerodynamics that affect this small model of an automobile really make a difference in its performance, or is it simply the mass of the vehicle, the friction in the axles, and the alignment of the components? We might be surprised if we could scientifically analyze the factors that differentiate a winning car from one that fails.

Why have we done this project (or problem, or learning activity, or module, or what-have-you) for such a long time? I would argue that it is because it is fun! There is nothing wrong with doing something that is fun, but sometimes having fun can cloud what students are really learning from the experience—both can and should occur simultaneously, especially in our field.

There are two developments that can breathe some learning life into the Metric 500 car. One is the instructional material developed by the TechKnow Project (http://www.ncsu.edu/techknow/aboutproject.html) that includes a powerful learning unit based around the car. The second is the Jaguar F1 Team in Schools project (http://www.f1inschools.us/) in which students design their cars using 3D modeling software and then produce it using a computer controlled milling machine driven by the parameters of the solid model.

Is the CO_2 powered car a project or simply a learning activity that is fun? The answer lies with the teacher and how it is implemented. One thing for sure, though, the project method is alive and well and gaining tremendous momentum, led in part by the internationally renowned M.I.T. Distinguished Professor, Seymour Papert. The George Lucas Foundation has developed a video tape titled *Teaching in the digital age: Project-based learning and assessment* (http://www.edutopia.org/products/tdapbl.php) for which Papert served as an advisor. It highlights exemplary practices in project-based learning and offers a very convincing rationale for it. I felt elated that several of the examples were from technology education and found it interesting to learn what other subjects in the school are doing with it as well. The Lucas Foundation publishes *Edutopia*, a practical and informative publication on education in which a significant number of articles on project-based learning have appeared over the past several years.

When I first started playing football in elementary school, I intercepted a pass from the opposing team. I can still conjure up the tremendous feelings of success that I felt, hearing the "crowd" cheering as I crossed the goal line. I can also recall the emotions that I felt when I realized that I had run the wrong way and the cheers were coming from the other team!

We can continue to be an increasingly formidable team in the educational enterprise. We have the best combination of cognitive, psychomotor, and affective players available. We have a good offense and a good defense, along with experiences and abilities that none of the other teams have. We just need to be sure that we are really running in the right direction and those who are cheering for us are doing so for the right reasons.

JEL

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Articles

Moving towards Technology Education: Factors That Facilitated Teachers' Implementation of a Technology Curriculum

Roy Barnes

Australia has a National Technology Statement (Curriculum Corporation, 1994) that specifies the content and process of technology studies in schools. However, as in the United States, the implementation of curricula is a state responsibility. In the state of Queensland the implementation has been a very gradual process with schools having the option of adopting new curricula on a school-by-school basis or waiting until implementation becomes mandatory in 2007. The introduction of school-based management has augmented the localization of decision-making about curricula. Decisions about curricula in resource intensive areas such as technology education tend to reflect local priorities. As a consequence, the technology curriculum in many schools reflects a pre-1980's industrial training orientation (Warner, 2001).

To a large extent, technology teachers have adopted a wait and see approach (INTAD, 2001), and are expecting a systemic curriculum direction, professional development, and the provision of resources (Warner, 2001). These teachers are now "at the extreme edge of knowledge and understanding of the content and pedagogical philosophy for the delivery of new technology curriculum" (INTAD, 2001, p. 2). Failure to implement the new curriculum may jeopardize the future viability of the subject area, as there is no statutory obligation for schools to offer specialized technology subjects.

Against this general trend, a core group of approximately 40 progressive teachers, from a total cohort of about 1150 (Warner, 2001), have chosen to implement a school-based technology curriculum. These teachers have modified the existing shop-based syllabi and pre-empted the new technology curriculum mandate (Warner, 2001). This situation poses a question that has formed the

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basis of this research. What factors have influenced these junior secondary school traditional technology teachers to implement a new technology education curriculum?

Literature Review

Historically, changes in technology curriculum have been successful only when initiated by classroom teachers (Waltisbuhl, 1995). Green (1986) supports this view, but adds that a new curriculum has not been implemented in technology because the "teachers' attitudes are steeped in prescriptive methods derived from nineteenth century practice" (Green, 1986, p. 27). "These attitudes have to be challenged and shown to be inadequate to the current situation and new-ideas, programs and practices that are meaningful, feasible, and usable have to be proposed" (Bybee & Loucks-Horsley, 2000a, p. 16).

Researchers have found that in the implementation of systemic educational reforms, the attitude of the classroom teacher is crucial in determining the success or failure of innovative curriculum (Hargreaves, 1994; Sarason, 1991). To implement changes, teachers must agree with the underlying philosophy of the curriculum (Stein, McRobbie, & Ginns, 1999). Changing a teacher's philosophy requires teacher development, which is a career-long process (Brady & Kennedy, 1999). Without teacher development there is no curriculum development and, conversely, where a curriculum has changed, there has been teacher development (Givens, 2000).

Implementing teacher development strategies is problematic. Teachers acknowledge the existence of programs, policy, directives, school regulations, and recommendations but in practice they often feign what needs to be done to comply with requirements. The curriculum students actually receive is influenced by what teachers believe, by what peers believe and do, and by other more elusive cultural issues (Sergiovanni, 1996; Wallace, 1998).

Hargreaves, (1997) has proposed that theories of educational change have been ineffective because they focused on technical planning. These theories of educational change were developed within a positivist epistemology that provides "a set of logical rules of explanation, independent of the world and its social practices" (Usher, Bryant, & Johnston, 1997, p. 176). The social aspects of change are therefore ignored. Support for new theories of educational change is based on a conceptualization of social reality that recognizes knowledge as personal, subjective, and as being developed and interpreted within a unique social context (Cohen & Manion, 1994). Researchers in education (Evers & Lakomski, 1996) are using this understanding of social reality to justify qualitative, or grounded, methods of research into the relationships of participants rather than the technical components of an educational social system.

This approach was deemed to be appropriate for this project as it provided an opportunity to discern some of the elusive attitudes, beliefs, and cultural matters which influence teacher development and therefore his/her role in the change process. An ethnographic study using data collection through narrative interviews was adopted. This provided an opportunity to focus on the individual, real-world experiences of the small group of unique technology teachers (Warner, 2001) who have implemented curriculum change. The analysis of the data is inductive, with theory emerging from, not preceding, the research (Cohen & Manion, 1994).

The literature review revealed a gap in knowledge in regard to factors that influence teachers to change curriculum content and practice. The selected methodology involved a reflective investigation of the experience of junior secondary school technology teachers who have implemented a technology education curriculum.

Methodology

Selection of Sites and Participants

Purposeful sampling was used to choose five information-rich schools in which teachers had voluntarily implemented technology education. The schools were physically different but similar in their approach to the subject area curriculum. This ensured that the study was sufficiently in-depth and focused on the topic. The sample size, according to the concepts of Lincoln and Guba (1985), should be large enough to provide informational redundancy. While the available time and resources have limited the sample size, it is not necessarily a problem for "there are no rules for sample size in qualitative inquiry. Sample size depends on...what will be useful, what will have credibility, and what can be done with available time and resources" (Patton, 1990 p. 184).

Participants were selected from a list, provided by the Industrial Technology and Design Teachers' Association of Queensland (INTAD), of exemplary teachers implementing a technology curriculum in their school. This list was reduced to six teachers by cross-referencing with a list of schools that had been invited to participate in a Queensland government technology key learning area syllabus trial. Teachers in these schools had implemented a technology curriculum voluntarily, prior to the syllabus trial, and their programs were used as the basis for the initial in-service materials. Three teachers declined to be involved, one due to ill health. Due to concerns regarding the limited opportunity for informational redundancy with a sample size of three, two more participants were sought. They were identified through the professional reference of a university lecturer.

Narrative Interviewing

In the context of this project, narrative interviews were in the form of a discussion of the research question. Each participant was encouraged to narrate the story of his/her experiences during the period when they were changing the curriculum. This style of interview creates a conversational encounter that allows the interviewee to tell a story in his/her own way and the interviewer the freedom to respond to new material raised during the interview. Data were collected from each participant in his/her own school environment using an audiotape.

Data Analysis

Initially, each participant's interview was read and studied to obtain a 'feel' for the individual's story. The participants had recorded a brief resume and this was used as the basis for a descriptive profile that outlined his/her career and the process by which he/she had experienced curriculum change. The finished profile was emailed to each participant and his/her feedback sought to ensure he/she was not being misrepresented. As a result of completing the profile a much deeper understanding of the unique themes and issues within each individual's interview data was gained.

The next step in the analysis of the data involved an inductive two-stage process. First, a list of the frequently recurring themes and issues was prepared for each individual. The groups of supporting text for each theme and issue were categorized and labeled as "factors." The result of this process was a new document featuring a set of factors that had influenced the participant along with supporting excerpts from the interview data. This was repeated for all the participants, one at a time and without reference to one another to minimize influence from previous data. The following sample demonstrates supporting extracts from the participant, (Oscar) of the factor "Personal Renewal."

Oscar described how a period of personal growth affected the way he viewed his job and the subjects he taught. Initially a number of significant changes occurred in his life and he began to question the usefulness of his subject area.

Oscar: I had to really evaluate what I was teaching for. Whether I was baby sitting classes and teaching something traditional...we were one of those subjects that didn't really matter.

Oscar returned to University to upgrade his Diploma of Teaching to a Bachelor of Education. This period of part-time study coincided with personal and spiritual growth. He stated that this released his creativity and an understanding of his role as an educator.

Oscar: Just about at the same time I'd been doing some studies for my Bachelor of Education ...through a process of prayer and discovery etc and just opening myself up I guess, a lot of ideas started flowing, that I found the students responded to very well." "...really made me start to think more deeply and value the skills that I had and the skills that I was teaching students, just the processes we were going through, I realized for a lot of kids they had a lot of value.

A technology teacher from another state with broader experience in technology education was employed at the school. This teacher became a mentor to Oscar and challenged him with new concepts and ideas about the subject area and the content.

Oscar A teacher from Tasmania who, greatly influenced ...I gained a new perspective. He caused me to start thinking more creatively, to see my subject as something of value.

These issues combined to change the way Oscar viewed his subject area and its future. As a result he decided to implement a new curriculum.

Oscar ...combined with a new creative thrust, it sort of turned my whole teaching career around, but I felt once again that I was doing something valuable. And that's persisted until this day... and from that time, we decided to abandon traditional manual arts projects and combine the design approach.

The second stage of the analysis involved identifying and labeling factors that were common to a number of participants. These were then documented in a narrative format and illustratively grounded in as much supporting raw data as possible. The factors were subjected to an extensive literature review to ascertain whether or not a relationship existed between the identified factors and any existing theory. From the relationships between the factors, two emergent models of curriculum change were proposed.

The Factors

A factor, in the context of this study, is defined as an influence that existed prior to the change and therefore influenced the teacher to initiate the change process.

Flagging Student Interest

"Flagging Student Interest" influenced the teachers' decision to maintain or change the current curriculum. The participants described a process whereby a lack of student interest in a subject initiated change. The students' needs tailored the new curriculum and once a new curriculum was implemented the students' enthusiasm provided the impetus for the ongoing change process. Stein, McRobbie, and Ginns (1999) proposed that before teachers fully embrace the new beliefs and practices of the technology curriculum, they need to experience the value through the changes in student learning. In this project the students' change from boredom with the traditional program, to a positive response to the technology curriculum, has encouraged the teachers to rethink their attitudes to existing curricula.

External Curriculum

"External curriculum" influenced the participants to adopt a technology education focus to the curriculum change that they planned. At the time that the participants were initiating curriculum change, the only curricula in the technology area were the 1986 traditionally based, Shop A (woodwork) and Shop B (metalwork). Teachers stated they were influenced by overseas curriculum directions in countries such as New Zealand and the United States and by changes in curriculum in other states of Australia.

This exposure to external curricula was by accident rather than design, but the effect fits with Fullan's (1999) top/down and bottom/up explanation of the process of change. Fullan argues that the provision of systemic policy must be accompanied by a simultaneous desire for classroom innovation. In this study the external curriculum influenced the teachers at a time when other factors such as flagging student interest were present. This may explain why minimal exposure to external curricula has contributed to the actions of these teachers in changing the existing curriculum.

Supportive School Environment

"Supportive School Environment" describes the internal school political milieu that appeared to have supported and encouraged the participants' to change the curriculum. The contributors to this environment were the principal, head of department, technology staff, school council, and parents. The nature of the school environment appeared to affect all of the participants. Some had tried to implement changes at previous schools but were unsuccessful because of a hostile or apathetic attitude to the new subject direction. The main underlying theme that the participants described involved the administration giving them the freedom to change.

An investigation of the literature from previous research indicated that a supportive school environment is a fundamental requirement for the successful implementation of new curriculum (Bybee & Loucks-Horsley, 2000a; Penney & Fox, 1997). This environment includes time, materials, and organizational structures that encourage people with ideas and collaborative opportunities for professional dialogue (Penney & Fox, 1997). These strategies, especially opportunities for professional dialogue and structures that encourage ideas, allow teachers "freedom" similar to that described by the participants in this project.

Peer support is a factor that is well documented in previous research. The attitude of the classroom teachers defines the day-to-day environment in which the innovative teacher works. As Givens (2000) stated, "innovation cannot succeed unless the majority of staff are at worse neutral but it is clearly important to have a majority positively inclined to the curriculum change" (Givens, 2000, p. 74). This is particularly so in the case of department heads: when they helped provide a supportive environment, teachers began to change the curriculum.

Personal Renewal

"Personal Renewal" describes a process of personal reflection and development that changed the teacher's belief in technology education. The result was a philosophical shift towards the ideals of contemporary technology education prior to implementing changes in the curriculum. The process was induced by separate elements such as career dissatisfaction, the influence of peers or mentors, further study, and spiritual enlightenment.

Four of the participants were trained as traditional industrial arts teachers and were not exposed to the elements of personal renewal until they had been teaching for at least 15 years. They reported experiencing a period of dissatisfaction with their jobs and the subject area, which led to a period of personal reflection. Bascia, (1998) maintained that teachers experience four distinct phases of personal growth as they progress through their careers. First, when teachers enter the profession they are initially concerned with survival. Second, they begin to question their suitability to the teaching career. Third, once the first two concerns are satisfied they enter a phase where they look for ways to improve their teaching abilities. In the fourth phase they experience a desire to influence other teachers. Effective teacher development usually takes place in a teacher's third phase of personal growth. It involves the teacher challenging their old beliefs and forming new beliefs, developing knowledge and learning new skills (Bybee & Loucks-Horsley, 2000b). This is the process of personal renewal described by each of the experienced teachers.

Leadership Style

"Leadership style" describes the personal characteristics that dictated the response of the participants when acted upon by the other factors. This factor emerged from the data as a dual factor since two different forms of leadership were apparent: "Trendsetter" and "Promoter." A trendsetter in this context is a person willing to accept new ideas and implement them when no one else is interested and to set an example through direct leadership that others follow. Four of the participants in the study acted as trendsetters in the manner in which they have implemented the technology education curriculum.

The promoter leadership style describes one participant's approach to the change process. His leadership style emerged from the data as a supporter of change rather than a driver of change. He is a department head with a half teaching load. In his department he allowed the teachers freedom to initiate a new curriculum and pro-actively lobbied the school administration to change perceptions and attitudes to the subject area. He continually used the term "we" and credits the changes that have occurred to a collaborative effort. In this way he is very different from a trendsetter as he has not led the curriculum change through personal implementation. He provided support to other teachers who wished to develop and try out the new curriculum. Subsequently, he also implemented the new curriculum into his own classes. As a result of his leadership style, he has contributed to the provision of a supportive school environment that is one of the key strategies for educational change in schools (Fullan, 1998).

Active leadership in school curriculum change is an important component of a systemic educational change strategy (House & McQuillan, 1998; McLaughlin, 1998; Penney & Fox, 1997). Research by Cranston (1999) of the leadership roles of teachers in the context of a school based management structure found that the school structure applies pressures on teachers to accept greater responsibility as leaders. This pressure will develop teachers as leaders if it is accompanied with the opportunity to learn leadership skills, knowledge, competencies, and attitudes. Whether leadership has a relationship to the teacher's innate personality is not discussed, as the broad focus of the literature is towards strategies that can be implemented by all teachers. However, four of the participants in this study believed that their innate personalities motivated their leadership styles both in the school community and within their personal lives.

Emergent Models of Curriculum Change

The five factors, flagging student interest, external curriculum, supportive school environment, personal renewal and leadership style form a system of change which has influenced the participants to introduce a non-systemic curriculum change. In the context of this project the term "non-systemic" refers to a situation where there is limited curriculum provision, direction, and implementation strategies provided by relevant educational organizations. The factors are interrelated and have provided a simultaneous influence on the participants. Further investigation of the data revealed that the participants' leadership style contributed to this phenomenon and formed the nucleus of two emergent models of curriculum change in technology education.

Trendsetter Model

The first model was labeled the "Trendsetter model of non-systemic curriculum change in technology education." (see Figure 1) Flagging student interest raises the trendsetter teacher's awareness that there is a problem with the existing subject while personal renewal provides the process of teacher development that is required for them to begin to question his/her belief in technology education. A trendsetter teacher influenced by flagging student interest and undergoing a personal renewal is searching for a direction of action

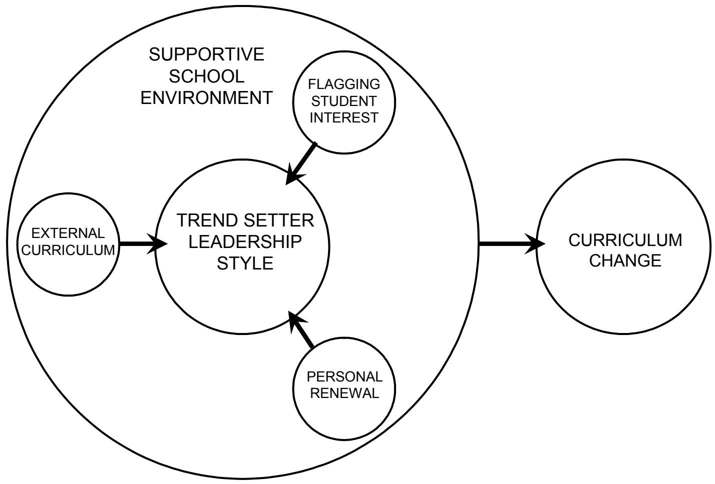

Figure 1. Trendsetter model of non-systemic curriculum change in technology education.

that will meet the needs initiated by these factors. Exposure to external curriculum focuses his/her energy on the curriculum change process. When these three factors are influencing the trendsetter teacher, a desire to change the curriculum is initiated. Teachers influenced in this manner require a supportive school environment before they are able to implement curriculum change. This environment must allow the teacher freedom to explore and trial new curriculum directions.

Promoter Model

The second emergent model of curriculum change is the "Promoter model of non-systemic curriculum change in technology education." (see Figure 2) This model is based on the experience of one participant who demonstrated an encouraging and supportive leadership style. The promoter teacher is willing to accept new ideas but does not personally lead the active implementation of the innovation. Instead, once the teacher believes in the ideals of technology education, they systematically and purposefully support the work of others. The model therefore involves a promoter leadership style nucleus that is acted on by the three factors: flagging student interest, external curriculum, and personal renewal. This cluster of factors influences the promoter teacher nucleus to produce a desire to promote and support curriculum initiatives of other teachers. These actions contribute to the development of a supportive school environment that would be conducive to the activities of a trendsetter teacher. The two models of curriculum change may therefore interrelate.

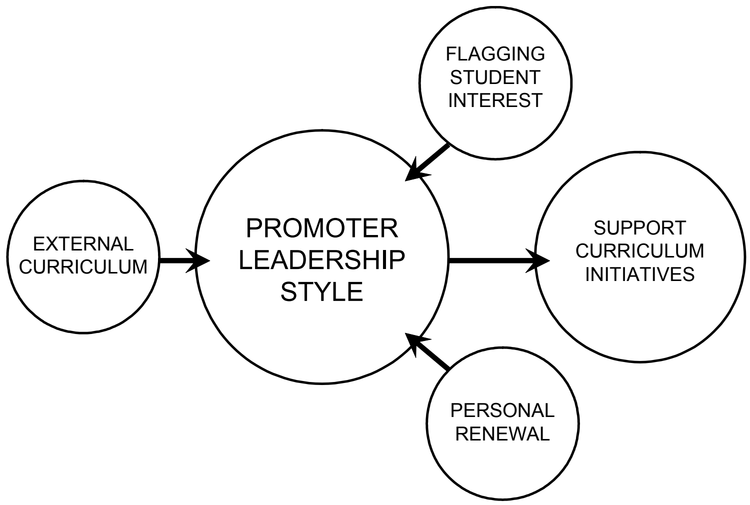

Figure 2. Promoter model of non-systemic curriculum change in technology education.

Conclusions and Recommendations

This project was unique on two accounts. Firstly, limited research has been undertaken into changing curriculum practice in technology education and secondly, due to the school-based management framework in Queensland, the changes have been implemented in a non-systemic curriculum environment. The conclusions and recommendations of this qualitative study are context-bound and provide an opportunity for researchers and teachers to increase their insight and understanding of phenomena and are not concerned with the broad generalization of results (Kantor, 1997). This study focused on identifying factors that influenced a small group of Queensland teachers to implement a new technology curriculum voluntarily. Narrative interviews were conducted and a qualitative analysis followed which emphasized the importance of the subjective experience of the individuals. Five important factors emerged from an analysis of the narratives. These were, flagging student interest, external curriculum, supportive school environment, personal renewal, and leadership style.

Flagging student interest created a need for change due to the decline in subject area enrollment. Once teachers initiated a trial technology education program, the resultant positive student interest motivated the teacher to continue developing the curriculum. The students' response generated a formative assessment of the curriculum changes and positively influenced the teachers' attitude about the new curriculum. A process of evaluation and positive teacher attitude are elements recognized in educational change literatures, but the role of students in influencing teachers to change curriculum is an area requiring further research.

External curriculum provided the direction for the curriculum change. One participant was from New Zealand where he was influenced early in his career by a national change from industrial arts to a design-based curriculum. Exposure to associated syllabi in current use in other Australian schools influenced the other participants.

A supportive school environment was crucial to the implementation of the new curriculum for all the participants. This included the support of the department head and fellow teachers. The teachers implemented changes to the technology curriculum when they were given freedom to experiment and try new ideas. Previous research describes a supportive school environment in terms of the provision of school structure rather than teachers' freedom. Future research may help schools provide the most suitable supportive environment for teachers trying to implement a curriculum change.

A process of personal renewal changed the beliefs of the teachers regarding their philosophical understanding of the subject area prior to curriculum changes. The personal renewal of the teachers was initiated by a sustained period of teacher development such as a course of study or mentoring by peers. This is consistent with the literature and has implications for practice. Teacher development requires continual professional and personal growth that encourages reflection and discovery about their teaching practice and subject content.

Two leadership styles were evident, trendsetter and promoter. These appear to be dependent on the innate personality traits of the teacher and dictate how he/she will react to the influences of the other factors. The trendsetter leads by implementing the curriculum personally, whereas the promoter supports other teachers, encouraging them to implement their ideas. The literature supports the need for a strong curriculum leader within the school. Further research may ascertain whether the leadership style is an innate or a learned strategy.

As an outcome of the research, two emergent models of non-systemic curriculum change in technology education have been proposed which are based on a trendsetter or promoter leadership style. The trendsetter model proposes that a teacher using this leadership style, when influenced by flagging student interest, external curriculum, and personal renewal, will implement a curriculum change if they are in a supportive school environment. A teacher using the promoter leadership style when influenced by the same three factors will seek to provide support for the curriculum initiatives of their peers. The two models are interrelated as a promoter may contribute to the creation of the supportive environment required by a trendsetter prior to implementing a new curriculum.

This research also identified two factors, personal renewal and supportive school environment, that may be developed to assist teachers' receptivity to the change process. Effective personal renewal may be initiated by the provision of a sustained period of professional development that encourages reflection and self-discovery. A supportive school environment may be enhanced by the employment of a teacher, preferably the department head, whose leadership style is that of a promoter, who can support other teachers and encourage them to implement changes.

The conclusions and proposed models provide future researchers and practitioners with context-relevant data that may be used as the basis of further research. The recommendations for areas of further research are:

- To verify the five factors identified in this project.
- Investigate the influence of students on curriculum change.
- Investigate the nature of the supporting environment within which curriculum change occurs.
- Study the nature of the trendsetter and promoter leadership styles in order to ascertain whether they are innate or learned.
- Study the emergent models of non-systemic curriculum change in Technology Education.

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A Systems Approach for Developing Technological Literacy

Moti Frank

In order to examine the implications of applying a teaching strategy that integrates a systems approach and project-based learning (PBL), it was implemented in two courses. The objective of the first course was to train pre-service teachers to teach the subject of "science and technology for all." The second course was an introductory freshman course in the Faculty of Mechanical Engineering. This paper describes a qualitative study that followed the progress of the two classes. The students in the courses were the participants in the study.

In order to prepare pre-service teachers to teach the subject of "Science and Technology to All" (mandatory subject in all of Israel's junior high schools), a mandatory methods course has been developed in the Department of Education in Technology and Science at the Technion – Israel Institute of Technology: "Methods for Teaching Science and Technology for All". The course participants were pre-service teachers who were studying toward a teaching certificate in the Department of Education in Science and Technology parallel to their studies for a B.Sc. degree in one of the Technion's science Faculties. Most students in this course lack basic knowledge in engineering and technology. The course lasts fourteen weeks (one semester). Every once-weekly class meeting includes a one-hour lecture, two hours of microteaching, and three hours in a lab (team project). The challenge for the course instructors was two-fold. First, students had to be given content knowledge. That is, they had to be taught technological subjects as they appeared in the national curriculum of the junior high school science and technology course. Second, students needed to acquire pedagogical content knowledge so that they could teach the subject content in the future.

The idea underlying the second course was to achieve certain objectives through experiential learning. These were to provide students with a clear overview of the different fields in mechanical engineering; to introduce them to the essence of engineering work and the processes of design and development of new technological products; to raise their awareness of the importance and necessity of analysis for finding optimal solutions for engineering problems, and

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to acquaint freshmen with the Faculty of Mechanical Engineering and familiarize them with the different aspects of mechanical engineering expertise (Elata & Garaway, 2002).

In both courses it was obvious from the start that the objectives could not be met in a 14-week semester if they were taught in the traditional way. Therefore, it was decided to try to implement a systems approach in a project-based learning environment (PBL). The concept of teaching/learning via a project is not new. The innovation here is the integration of PBL and the systems approach, and the implementation of this combination in courses that up until today had been taught in traditional ways. This was an attempt to exploit this integrated approach to teach technology through a top-down process, without explaining the details to students lacking a technological background. This paper presents what was learned during implementation of this approach in these two courses, as well as thoughts on future implications.

The Systems Approach in Technology Education

The traditional approach in engineering or technology teaching is bottom-up, i.e. from component to system. For example, the order of the courses in a typical communications engineering program is: mathematics (calculus, etc.), science (physics, etc.), electricity basics, components, linear circuits, modules, basics of transmission and receiving, subsystems, and communications systems. In most traditional curricula, both in high school and undergraduate programs, the stage of dealing with a complete system is sometimes not fully addressed by the curriculum.

The larger, more complex, more dynamic and more interdisciplinary the specifications for a technological systems get, the harder it is for a lone engineer, as skilled as he or she may be, to design a complete system. Given this, students and their teachers, who are not required to be proficient in engineering, but who should be technologically literate, should not be expected to know so much as trained engineers as they go about manipulating entire technological systems.

Based on the systems thinking approach, what follows is a proposal for a way to teach technology and instill technological literacy without first teaching the details (for instance, electricity basics and linear circuits for electronics, or calculus and dynamics basics for mechanical engineering).

The central idea in this premise is that complete systems can be handled, conceptually and functionally, without needing to know their details. According to this approach, when trying to develop technological literacy in students who are not required to be proficient in engineering, the favored teaching strategy is top-down. In other words, the focus must be on the characteristics and functionality of whole systems and the interdependences of the subsystems.

The Main Benefits of the Project-Based Learning Approach

In PBL, learning comes through a process in the framework of which students, working in teams, build a product. The product may be something tangible (such as a model/prototype, a system or a robot), a computerized product (such as software, a presentation, or a multimedia product), or a written product (such as a report, an evaluation summary or a summary of experimental findings). The product must answer a question, solve a problem, and meet requirements or needs set by the course instructor or identified by students. In the courses described herein, students were assigned to build a tangible product. Some examples include a car driven by solar energy, a remote cardiologic testing system, an automated watering system, a hot air balloon system, an automated purification system for aquarium water, a bridge of straws, and a tea cart.

According to Krajcik, Czerniak and Berger (1999), and Buck (1999), students in PBL are engaged in active learning and gain multidisciplinary knowledge while working in a real-world context. The importance of student engagement is widely accepted and numerous researchers have provided considerable evidence to support the effectiveness of student engagement on a broad range of learning outcomes (Prince, 2004; Hake, 1998; Redish, Saul, and Steinberg, 1997; Laws, Sokoloff, & Thornton, 1999). Bonwell and Eison (1991) summarized the literature on active learning and concluded that it leads to better student attitudes and improvements in students' thinking and writing. According to Hill and Smith (1998), the project-based courses in technology education use design processes. Since design does not happen by default, a design process must become part of the course curriculum and students must be guided through the process.

Green (1998) noted that project learning increases motivation to study and helps students to develop long-term learning skills. Students know that they are full partners in this learning environment and share the responsibility for the learning process. Green also stated that this approach helps to develop a long-term learning ability. Krajcik et al. (1999) suggested the following three benefits for the student: first, learners develop deep, integrated understanding of content and process; second, this approach promotes responsibility and independent learning; and third, this approach actively engages students in various types of tasks, thereby meeting the learning needs of many different students (see also Hill & Smith, 1998). Krajcik et al. (1999) indicated that PBL offers multiple ways for students to participate and demonstrate their knowledge that can be matched to the various learning styles of students. In some studies, a positive correlation was found between self-esteem and success and receiving a positive assessment (Battle, 1991). Hill and Smith (1998) also found that the PBL environment in their courses increased students' self-confidence, motivation to learn, creative abilities, and self-esteem.

In research described by Shepherd (1998), it was found that grades for the Critical Thinking Test received by students who had learned in a PBL environment were significantly higher than those of students in a comparative group, who had studied in the traditional fashion. The PBL students also demonstrated greater self-confidence and an improved learning ability. Norman and Schmidt (2000) pointed out that having students work in small teams has a positive effect on academic achievement. In a review of 90 years of research, Johnson, Johnson, and Smith (1998) found that, across the board, cooperation improved learning outcomes relative to individual work, including academic achievement, quality of interpersonal interactions, self-esteem, perceptions of greater social support, harmony among students. Team work is a central characteristic of PBL. In most cases, group decisions, expressing the various perspectives of a team's members, are better than individual decisions (Parker, 1990). One benefit of PBL is that students learn to work together to solve problems. Collaboration involves sharing ideas to find resolutions to questions. In order to succeed in the real world, students need to know how to work with people from different backgrounds (Krajcik, Czerniak & Berger, 1999).

The Principal Challenges in PBL

The following elaborates the challenges facing instructors wishing to integrate PBL into their teaching. First, team work requires interpersonal skills such as communication skills, negotiation skills, and an ability to cope with conflicts (Hertz-Lazarowitz, 1990). The second challenge relates to the large amount of time that the teacher invests to implement PBL. Another challenge is the need to cope with new course content in a learning environment that is neither structured nor organized in advance. Thus we see that teaching by means of PBL presents several challenges. These include students' lack of experience in this new approach and their preference for a traditionally-structured approach; their preference for a learning environment that requires less effort on their part; and problems arising from time pressures. Students struggling with ambiguity, complexity, and unpredictability are liable to become frustrated in an environment of uncertainty, where they have no notion of how to begin or in which manner to proceed. The PBL method is rather time-consuming and requires the teacher to invest a lot of effort over an extended period of time. Class management, in which the students have the freedom to talk together, is often more difficult. Teachers regularly feel a need to direct lessons to ensure that students get the "right" information. Teachers frequently give students too much independence without structuring the situation, or providing feedback (Krajcik et al. 1999, pp. 322-328; Buck Institute of Education, 1999, Potential Problems section).

Method

In the two courses included in this study, students were required to design and build a physical model of a technological product/artifact/system based on scientific, technological, social and environmental principles. To emphasize technological and not merely scientific literacy, the unique feature of the projects was their starting point—technological requirements and needs rather than a research question as in project-based science. Students first defined what would be required of the system. They investigated alternatives for implementation, collected and analyzed data through a process of investigation and collaboration, and then conducted a trade-off study. Having done all this they designed the system, using a top-down approach.

The teaching staff of both courses directed students to choose subjects for their projects such that their process of working would serve the courses' objectives. The emphasis was on developing technological literacy in accordance with the course goals. During the courses, students' progress was continually observed and supervised by the teaching staff. Periodically students were required to submit a report about implementation versus design and a plan for further work and/or technical reports. At the end of the project students had to present their work to the teaching staff and their classmates, as well as submit summary group and individual reports.

The objective of the study that followed the progress of the two classes was to identify the benefits and challenges, from the perspective of the students, of the teaching strategy based on a combination of PBL and a systems approach for instilling technological/engineering literacy. There were 107 students who participated in the two courses: 62 students in the first course (given twice to two different groups) and 45 in the second course. The qualitative paradigm was found to be suitable for this study mainly because the study focused on processes as well as final outcomes, and on personal aspects such as students' thoughts, feeling, actions, and difficulties (Guba & Lincoln, 1985).

The study was carried out in three stages. In the first stage the researcher spent many hours in the role of "the-observer-as-participant" (Adler & Adler, 1994), conducting on-site observations at the classrooms. The second stage involved semi-structured interviews with eight teams of students, with three students in each team. The third stage consisted of a survey based on an open-ended questionnaire and on analyzing students' reports and products. The number of interviews and observations was not decided in advance. The criterion for stopping data collection was saturation; that is, additional interviews presented no significant new findings. The study structure was developed during the process of data collection, without prior assumptions. A spiral layout was employed—one that begins with an unknown, collects some data, updates and corrects, and so on (Spradley, 1980). The strategies adopted to increase the trustworthiness of the study were those suggested by Guba and Lincoln (1985). The data analysis strategy used was "content analysis": it defines the analysis units and establishes the *categories*, that is, the outstanding repeated elements, for analyzing the raw data.

Major Findings and Discussion

Analysis of the raw data collected from observations, interviews, questionnaires, and student reports and products revealed several frequently repeated items, which defined the categories as mentioned above. These items were classified into two meta-categories—benefits and challenges. Overall, fifteen benefits and three challenges were identified. They are presented in Table 1.

Table 1
The fifteen benefits and three challenges identified in the study

Meta-categories	No.	Categories
Benefits	1	Acquiring Multidisciplinary Knowledge
	2	Learning in Active Learning Environment
	3	Learning Through Meaningful and Authentic Learning
	4	Developing Information Literacy Skills
	5	Focusing on Synthesis Processes
	6	Experiencing Design Process
	7-8	Exploring the Top-Down Approach and Developing Capacity for Systems Thinking
	9	Executing Cost/Benefit Analysis
	10	Learning Project Management Methods
	11-13	Increasing Motivation, and Developing Independent Learning and Learning Skills
	14	Improving Academic Achievements
	15	Experiencing Team Work (Collaborative Learning)
Challenges	1	Facing Conflicts While Working in Teams
	2	Investing More Time and Effort
	3	Learning in an Unstructured Learning Environment

Note: Please see in the Method section the strategies adopted to increase the trustworthiness of the findings. Triangulation was employed, i.e., categories not found in at least three interviews or in three observations were omitted.

The benefits from the perspective of students that may be derived by using a teaching strategy that integrates PBL and a systems approach will be presented below.

Acquiring Multidisciplinary Knowledge

Many students noted that in the course of the project they acquired multidisciplinary knowledge, which they believe is one of PBL's advantages. Other students marked the interaction between the team members as a means of acquiring multidisciplinary knowledge. Yet other students emphasized the importance of working as part of a team as a way of coping with a wide variety of issues and a large amount of information.

The students' perception of the multidisciplinary knowledge acquisition as an advantage of PBL was also manifested in their answers to the questionnaire. Based on their experience in the course, 95% of the students in the first course maintained that PBL allowed them to acquire knowledge and enhance their understanding of multidisciplinary subjects.

Indeed, according to Krajcik et al. (1999) and Buck (1999), students in PBL are engaged in active learning and gain multidisciplinary knowledge while working in a real-world context. In PBL environment the teaching/learning process can be directed for the acquisition of multidisciplinary knowledge by students. This finding is not surprising since the subjects of the projects were chosen such that, in order to carry them out successfully, students required knowledge of different disciplines.

The need to have multidisciplinary knowledge is becoming evident in every facet of life. For instance, in research done in industry (Frank, 2002), it was found that electrical/electronics engineers, who as undergraduates had taken courses in the area of electricity and electronics engineering, needed in their professional jobs additional information from areas such as software engineering, mechanical engineering, industrial engineering and management, quality assurance and sometimes aeronautical engineering as well. Multidisciplinary knowledge is a must today in research, development, teaching, industry, administration, and other areas as well. Over the past few years there has been a rise in the number of multidisciplinary study programs being offered by academia.

Learning in Active Learning Environment

Another advantage identified by the students in a PBL environment is that learning is active and experiential. While collaborating on projects, they acquired knowledge through active and interactive learning. Other students emphasized the intensive activity of searching and sorting through relevant interdisciplinary information. Indeed, about 80% of the students in the first course strongly agreed that learning in a PBL environment is active and experiential learning—as opposed to other lecture-based courses where they have a passive role only.

These findings are also substantiated by the literature. The importance of student engagement is widely accepted and numerous researchers have provided considerable evidence to support the effectiveness of student engagement on a broad range of learning outcomes (Prince, 2004; Hake, 1998; Redish et al., 1997; Laws et al., 1999). Bonwell and Eison (1991) summarized the literature on active learning and concluded that it leads to better student attitudes and improvements in students' thinking and writing.

Many elements of active learning are derived from the constructivist teaching approach. Constructivism is a theory concerning learning and knowledge that suggests that humans are active learners who construct their knowledge based on experience and on their efforts to give meaning to that experience (Glasersfeld, 1995). In the courses presented here, students were required to construct their knowledge by means of active experience and learning by trial and error.

Learning Through Meaningful and Authentic Learning

The teaching staff in both courses directed students to deal with real-life areas and situations in the framework of their projects. When students are involved in realistic and relevant topics, the chances are greater that their learning will be meaningful. Meaningful learning occurs when the student sees the teaching material as related to his or her objective (Rogers, 1969). Since students deal with relevant issues, their motivation is increased (Green, 1998).

Some students mentioned the relevance as a learning-motivation enhancing factor. And indeed, in answering the questionnaire, about 85% of the students in the first course agreed that working in a PBL environment strengthened their learning motivation and sense of responsibility. About 90% of the students agreed “to a large/very large extent” that PBL allowed them to be engaged in everyday relevant issues.

Developing Information Literacy Skills

From an analysis of the raw data collected during observations, it became clear that students were required to develop different skills. These ranged from inquiry and problem solving skills, to ones for handling information (locating, evaluating, analyzing, presenting, sorting, using, organizing, processing, finding, retrieving, identifying, and integrating information), through thinking skills (such as creating thinking), and various laboratory skills (such as building models/prototypes, measuring, and troubleshooting).

Focusing on Synthesis Processes

Traditional teaching methods stress the importance of analysis processes. According to Bloom’s taxonomy, analysis is the disassembly of a unit of content into its component elements while retaining the components’ interconnections. The purpose of analysis is to arrive at an understanding of the content components. Similarly, system analysis is the disassembly of the system into its components with the purpose of analyzing its operation. Some researchers assert that analysis is a way to acquire knowledge and understanding.

In contrast to this, in a PBL environment, students experience synthesis processes. Synthesis is the combination, arrangement, organization, and assembly of elements and parts with the purpose of creating a system that did not previously exist. Synthesis is the connection of components or sub-systems into a whole system. In a PBL environment students choose appropriate elements from different sources and join them together in order to create the final product required by the project.

Experiencing Design Process

The findings also distinctly showed that the students had been exposed to engineering design procedures, and to the basic principle of systems engineering, in which an engineering/technological project begins with a requirements analysis. Under the guidance of the teaching staff, students in both courses performed the following stages in executing their projects: needs identification, requirements analysis, a trade-off study based on collection and analysis of data, defining alternate solutions and presenting with each one the benefits, disadvantages, costs, resource requirements and estimated time schedule, selection of the optimal alternate solution, pre-design, detailed design, model or prototype building, and evaluation of the model/prototype.

Indeed, according to Hill and Smith (1998), the project-based courses in technology education use design processes. Because design does not happen by default, a design process must become part of the course curriculum and students must be guided through the process.

The students in the course presented by Verner and Hershko (2003) also went through all stages of interdisciplinary design. In order to execute their projects, the students went through six design stages: project idea, specification, concept design, detail design and creation, operation and tuning, and evaluation.

Exploring the Top-Down Approach and Developing Capacity for Systems Thinking

In the course of completing their projects students were required to simultaneously use top-down and bottom-up approaches. The design was executed according to the former—defining the systems requirement, doing the pre-design and moving to detailed design. The production, integration, and tests were conducted according to the latter approach—joining several components, assembly testing, adding components, re-testing the new assembly, and so forth until assembly and testing of the entire product.

As they were executing the project, students had to "see" the whole (the final product) and understand the interrelationships and interdependencies among the components of the product that they were attempting to design and build. This galvanized students into improving their systems thinking abilities. By observing the students activities while working on the projects it was clear that most of the students tried to begin by clarifying the "big picture" and consider the widest aspects of the system and the environment in which it should perform.

The ability to see the big picture is an important aspect of engineering, as has been shown in previous studies. For example, many interviewees in a study by Frank & Waks (2001) defined engineering systems thinking as the understanding of the whole system. A problem may not be optimally solved just by breaking it down into elements and finding a separate solution for each of those elements. One must be able to see the whole picture while considering particular solutions for different functions that compose the system (Senge, Kleiner, Roberts, Ross, and Smith, 1994; Senge 1994; O'Connor & McDermott, 1997; Kim, 1995; Waring, 1996). An engineer with a capacity for systems thinking is therefore an engineer who understands the whole—the entire system and the whole picture. He or she understands the whole system beyond its single components (part, box, card, element) and understands how the single component functions as part of the entire system or assembly. An engineer with a capacity for systems thinking also understands how sub-systems integrate into a whole single system, which should fulfill predetermined requirements and specifications.

From the students' answers, it seems that the awareness of the notion of a "big picture," even though this big picture may not be clearly seen, is of great importance in itself. For an experienced engineer, seeing the big picture means a concrete vision of the system in a large perspective. However, for inexperienced students, the realization that there is a big picture is an important first step.

Executing Cost/Benefit Analysis

Execution of the project exposed students to cost/benefit analysis considerations and to the need for trade-offs due to various constraints. Students learned through their experiences that they should not always opt for the solution with the best performance, but that rather they should seek the one that provides the optimal solution—and that these are not always the same.

In practice, the students conducted an intuitive trade-off study. There are multiple techniques for performing trade-off studies. Our students intuitively used the decision tree approach, i.e., they prepared a list of viable alternative solutions, a list of selection criteria (performance, weight, cost, etc.), a metric for each of the selection criteria, and assigned weighting values to each of the selection criteria.

Learning Project Management Methods

During the two courses, the instructors introduced topics from the area of project management such as project integration management, project scope management, project time management, project cost management, project risk management, and knowledge management (Laufer & Hoffman, 2000; PMBOK, 2000). Students in both courses were required to work according to these principles.

Increasing Motivation, and Developing Independent Learning and Learning Skills

There were students who felt that participation in and responsibility for the learning processes was greater in the PBL environment than in a traditional course. Many claimed that in PBL the responsibility for the learning devolves on the student. Other students mentioned the social pressure within the team as a factor that stimulated them to strive harder.

PBL essentially allows the student to adjust the rate and the level of learning according to his/her abilities. During observations, it was noted that in one of the courses the class was largely heterogeneous. In an interview, the teaching assistant affirmed that the rates of progress of the different teams obliged him to adjust the level of instruction accordingly. As the course proceeded and he adjusted the instruction and assignments for each team, he felt that those who had initially been weaker had improved greatly during the course, achieving impressive results. According to the follow-up of the different teams, the discrepancies between them decreased as the course drew to its close.

Many of the students also felt that this type of course increased their motivation to learn. They felt themselves called upon to exert themselves more in the right direction, and to persist. It is evident that students felt that the course developed their engineering thinking and their intuition, increased their motivation to study, permitted a rate and level of progress according to the needs of each team, and made the students feel that they were responsible for the learning process.

These findings are also substantiated in the literature. Green (1998), for instance, noted that project learning increases motivation to study and helps students to develop long-term learning skills. Students know that they are full partners in this learning environment, and share the responsibility for the learning process. Green also stated that this approach helps to develop a long-term learning ability. Krajcik et al. (1999) suggested the following three benefits for the student: first, learners develop deep, integrated understanding of content and process; second, this approach promotes responsibility and independent learning; and third, this approach actively engages students in various types of tasks, thereby meeting the learning needs of many different students.

Hill and Smith (1998) also found that the PBL environment in their courses increased students' self-confidence, motivation to learn, creative abilities, and self-esteem. It would certainly seem advisable for teachers of other school subjects to examine the benefits of moving from teacher-centered to student-centered courses and applying this model in their courses.

Improving Academic Achievement

What have researchers discovered about the usefulness of the PBL approach? In research described by Shepherd (1998), it was found that scores for the Critical Thinking Test received by students who had learned in a PBL environment were significantly higher than those of students in a comparative group who had studied in the traditional fashion. The PBL students also demonstrated greater self-confidence and an improved learning ability. In another study, students learning in a PBL environment showed significantly higher achievements than students who had been taught using traditional teaching strategies (Sabag, 2002).

Norman and Schmidt (2000) pointed out that having students work in small teams has a positive effect on academic achievement. In a review of 90 years of research, Johnson et al. (1998) found that, across the board, cooperation improved learning outcomes relative to individual work (academic achievement, quality of interpersonal interactions, self-esteem, perceptions of greater social support, harmony among students). Springer, Stanne, and Donovan (1999) found similar results looking at 37 studies of students in science, mathematics, engineering, and technology. In the courses described here, the students worked in small teams. The assessment in both courses was not based on exams, but building on the above-mentioned findings, it can be assumed that the learning was more effective than if a traditional lecture-based method would have been used.

Interestingly, Rosenfeld and Rosenfeld (1999) found that students with low academic records who studied in the conventional framework did better in courses based on PBL, whereas those with higher grades in regular studies achieved less when PBL methods were applied (or abandoned the project completely). Based on their findings, the researchers suggested that styles of teaching and learning environments should be adapted to the student's learning mode. Low academic grades do not necessarily demonstrate a lack of ability, but rather hint at the unsuitability of the pedagogic system. They recommended that students be exposed to PBL in order to give those who may be failing a chance of doing better, and to encourage those with high academic achievements in subjects taught traditionally to develop additional expertise.

Experiencing Team Work (Collaborative Learning)

In a PBL environment, students experience working as part of a team. The importance of this kind of experience, as part of their preparation for work life in the modern business world, is obvious. PBL provides a natural environment in which to promote effective team work and interpersonal skills. For engineering faculty, the need to develop these skills in students is reflected by the ABET engineering criteria. Employers frequently identify team skills as a critical gap in the preparation of engineering students (Prince, 2004).

Team work is a central characteristic of PBL. In most cases group decisions, expressing the various perspectives of a team's members are better than individual decisions (Parker, 1990). One benefit of PBL is that students learn to work together to solve problems. Collaboration involves sharing ideas to find resolutions to questions. In order to succeed in the real world, students need to know how to work with people from different backgrounds (Krajcik, Czerniak & Berger, 1999).

Team work is not a natural process arising from a meeting of a group of people. Rather, it is an *initiated* process that requires organizational activities and specific procedures over a period of time. The term "organizational activities" relates to such matters as distributing the agenda in advance, writing up protocols of meetings, defining the preparations needed, characterizing the ways of distributing the reports, nominating a leader, and determining the structure of the meetings such as reviewing the status of previous decisions, presenting a new subject, holding discussions, summing-up, and making decisions. "Specific procedures" are ones such as how decisions are made (vote, consensus, by the chairman, etc.), and how to cope with conflicts.

It is thus evident that in order to achieve effective learning in a team, the students must be trained in team work. A random collection of students does not necessarily make for an effective team (see also Hill & Smith, 1998). From the evidence that we collected, it is apparent that in the courses described here the students were not given any introduction to team work, and this impacted on the effectiveness of some of the teams.

For PBL to be an effective learning environment, students must be trained to work in teams, both before and during the project. This prepares them for coping with conflicts among team members, for making group decisions, for meting out tasks, and for the necessary organizational preparations. Thus, faculty should be trained in group mentoring. A trained instructor would better build the working teams and lead them to produce effective and synergic work.

Conflicts Students Faced While Working in Teams

The following elaborates the challenges facing instructors wishing to integrate PBL into their teaching. First, team work requires interpersonal skills such as communication skills, negotiation skills, and an ability to cope with conflicts (Hertz-Lazarowitz, 1990). From analysis of the students' personal reports, we learned that some of them were indeed exposed to situations of conflicts during the team work. Hopefully, experiencing conflict situations during their work with the team and working through them prepared the students to better coach their future pupils for working in a team.

Investing More Time and Effort Learning in an Unstructured Learning Environment

The second challenge, as identified by the students, relates to the large amount of time that the teacher invests to implement PBL. Another challenge faced by the students is the need to cope with new course content in a learning environment that is neither structured nor organized in advance.

Thus we see that teaching by means of PBL presents several challenges. These include: students' lack of experience in this new approach and their preference for a traditionally-structured approach; their preference for a learning environment that requires less effort on their part; and problems arising from time pressures. Students struggling with ambiguity, complexity, and unpredictability are liable to become frustrated in an environment of uncertainty, where they have no notion of how to begin or in which manner to proceed.

Conclusion

Analyzing the findings of this study leads to the conclusion that a teaching strategy that integrates a systems approach and PBL comprises a valuable tool for developing preliminary technological literacy among students who lack a technology/engineering background. In the context of this study the term "developing technological literacy" refers to the following dimensions: acquiring technological multidisciplinary knowledge, experiencing synthesis and engineering design processes, becoming familiar with the engineering top-down approach, performing cost/benefit analyses, and becoming familiar with the concept of engineering systems thinking, with some principles of project management.

From the students' point of view, this teaching strategy offers some valuable pedagogical benefits. The learning is active. Students deal with real-world authentic tasks and are likely to develop information literacy and independent learning skills. Their motivation is also liable to increase. They are exposed to and experience team work, and finally, their academic achievements are likely to be better than in traditional learning environments.

Nonetheless, this teaching strategy also addresses a few inherent challenges. First, team work requires interpersonal skills such as communication skills, negotiation skills, and an ability to cope with conflicts. From an analysis of the students' personal reports, it was clear that some students were indeed exposed to situations of conflicts during the team work. To mitigate this challenge, instructors should consider preparing their students for team work by having them participate in a pre-course workshop led by a team work expert. Second, this approach is rather time consuming and requires teachers and students to invest a lot of effort over an extended period of time. Practice may lead instructors to better manage courses based on this approach. Third, students in academic courses often lack experience in this approach and many prefer one that is traditionally-structured. Students struggling with ambiguity, complexity, and unpredictability are liable to become frustrated in an environment of uncertainty, where they have no notion of how to begin or in what manner to proceed. Class management, in which the students have the freedom to talk together, is often more difficult. Teachers frequently give students too much independence without structuring the situation, or providing feedback. To mitigate this challenge, instructors should consider integrating two approaches – the more structured teaching methods (lectures, discussions, presentations) and the method proposed in this paper (integrating systems approach and project-based learning). Usually, novice teachers lack the training necessary to teach PBL effectively mainly because they have not been trained in this area. Integrating PBL in teaching requires training the teaching staff both in the content knowledge as well as the pedagogical knowledge. Centers for staff development in some universities and colleges offer PBL workshops. Novice instructors are encouraged to attend a PBL workshop prior to the first time they implement this method.

This manuscript presented the findings of a qualitative study. Based on the results presented, a follow-up study that includes quantitative measurements is being designed. For example, a test for assessing the capacity for systems thinking is currently being developed. If such a tool existed, the effect of the teaching strategy presented here on the capacity for systems thinking of students could have been quantitatively measured.

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Creativity—A Framework for the Design/Problem Solving Discourse in Technology Education

Theodore Lewis

Subjects for which aesthetics and creative performance are critical curricular dimensions (such as art, physical education, music, and technology education), and which are accommodative of students across the range of intelligences (Gardner, 1999) are not readily or completely captured by content standards. Therefore content knowledge in these fields that target student achievement as conventionally conceived must be complemented by treatment of more subjective and elusive goals such as the development of connoisseurship, appreciation, or creative insight. With the publication of standards for the subject (International Technology Education Association, 2000), the need for focus upon creativity in technology education has been made more urgent than before because of the prominence given to the teaching and learning of design. Four of the standards (8, 9, 10, and 11) address design directly. Technological design is a medium through which dimensions of children's creative abilities can be stimulated and augmented. This creative potential of design teaching can be seen in the work of Druin & Fast (2002), where Swedish children who are included in the design of technology reveal inventive dispositions in their journaling. It can be seen also in the work of Foster and Wright, 2001; Gustafson, Rowell and Guilbert, 2000; Neumann, 2003; and Parkinson, 2001.

Arguably, stimulating creative impulses in children through design and problem-solving activities is as grand a goal of curriculum as is the achievement of particular design-based, measurable outcomes. But how do we get children to improve upon the quality of their designs? What makes one design solution more elegant than the other? There are no easy answers here because creativity does not quite respond to the accustomed inquiry questions that we pose in discussion of curriculum, instruction and assessment questions in technology education. As Bruner (1962) pointed out, creativity is a silent process which by its very nature will not be responsive to the processes ordinarily employed to determine content standards. Instead, it requires its own set of questions, including examination of its nature.

This article seeks to stimulate a conversation about the inculcation of creativity as an important goal of technology education, and as a concomitant of

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the goals of the Standards for Technological Literacy. The purpose is to direct the attention of the field to an area of the subject that remains under-explored. It could be argued that creativity underpins the substantial attention that has been devoted within recent times to design and problem solving. But much of this attention is implicit rather than explicit. There is a need for design and problem solving in technology education to be framed not so much in terms of methodologies of engineers, but as opportunities for students to step outside of conventional reasoning processes imposed by the rest of the curriculum. Creativity has compelling claims to being the anchoring idea in such a framework.

Should a conversation on the creative dimension of technology education blossom to the full, the result could be the unearthing of issues and challenges that could become the basis of a framework for research (see Lewis, 1999) and for re-consideration of technology-based curriculum and instruction. A creativity focus augments the content standards thrust by causing us to be preoccupied not just with student learning of technological concepts and processes, but with what children can learn about themselves by engaging technology. The article unfolds by addressing (a) what is creativity, (b) creative cognitive processes, (c) schooling and creativity, (d) creativity and technology education, and (e) implications for technology education.

What is Creativity?

Creativity is not easily defined, because of its unseen character. As Boden (1994) points out, inventors often do not know the source of their insight. Still, it is possible to discern the creative from the ordinary. Bailin (1994) notes that while there has not been universal agreement on what constitutes creativity, there are shared beliefs about its nature, as follows (a) that creativity is connected with originality—with a break from the usual (b) that the value of creative products cannot be objectively ascertained, since there are no standards by which new creations can be assessed (c) that beyond products, creativity can be manifested in new and novel ways of thinking that break with previously established norms (d) that existing conceptual frameworks and knowledge schema impose restraints on creative insight, and (e) that creativity is a transcendent, irreducible quality.

An enduring definition provided by Bruner (1962), is that creativity is an act that produces "effective surprise" p. 3. Bruner explained that the surprise associated with creative accomplishment often has the quality of obviousness after the fact. The creative product or process makes perfect sense—once it is revealed. For the creative person, surprise, according to Bruner, "is the privilege only of prepared minds—minds with structured expectancies and interests" p. 4. Bruner identified three kinds of surprise, *predictive* (such as in theory formulation or re-formulation), *formal* (as in a musical composition where there is an elegant reordering of elements), and *metaphorical* (as in the idea of "systems"), where the creativity comes from recognizing commonality across disparate elements.

Tardif and Sternberg (1988) suggested that it could be fruitful to dissect creativity into processes, persons, and products, and indeed, much of the research on creativity is framed along these lines. Creative processes take time, and include search through a problem space. They may involve transformations of the external word, internal representations through analogies and metaphors, constant definition and re-definition of problems, applying recurring themes, and recognizing patterns. Creative people are governed by internal factors, especially personality. They invariably are creative within particular domains, such as art, music, or electronics. But across domains creative people share common cognitive characteristics such as the ability to think metaphorically and flexibly, the ability to recognize good problems in their fields, and the willingness to take intellectual risks.

Composite Nature of Creativity

A view of creativity around which there has been a growing consensus that it is a composite concept, the product not just of individual traits, but also of societal and environmental factors. Csikszentmihalyi (1988) offered such a view, having proposed that creativity is never accomplished by an individual alone, but rather is the product of the interaction of a stable cultural *domain* that will ensure perpetuation of the idea, a supporting institutional framework (a *field)* comprised of the stakeholders and gatekeepers who affect the structure of the domain, and an *embedded social system*. By this way of thinking, attributions of what is creative are relative, and grounded in social agreement. Lubart (1994) wrote that to be creative is to produce work that is both novel and socially useful, and that the less parochial is the context of the accomplishment, the more highly creative is the work.

Creativity and Intelligence

Whether creativity correlates with or is completely explained by theories of intelligence has been a point of issue. The consensus appears to be that creative behavior has to be explained outside of the framework of intelligence. And indeed, Gardner (1999) has proposed that intelligence resides in a multiplicity of human attributes. In a seminal piece, Guilford (1950) suggested that to fathom creativity one had to look beyond the normal boundaries of IQ. He contended that creativity was not confined to geniuses, but rather, on the principle of *continuity*, it was present albeit in varying degrees, in all humans.

Feldhusen (1993) wrote that creativity has readying and predisposing conditions, one being intelligence, but that while intelligence is an asset, it is not a sufficient condition for creative behavior. Sternberg (1985; 1988) has contended that creativity overlaps with intelligence, cognitive style, and personality/motivation, and that it has socio-cultural as well as experiential correlates. While the intellectual dimension of creativity deals with problem finding, problem definition and redefinition, and knowledge acquisition, personality aspects govern traits such as tolerance for ambiguity and willingness to surmount obstacles.

Theories of Creativity

Several strands of theory support inquiry into creativity. Busse and Mansfield (1980) suggested seven lines, namely, psychoanalytic, Gestalt, associationism, perceptual, humanistic, cognitive developmental, and composite theories (such as Koestler's (1969) *bisociation*). Houtz (1994) condensed these lines into four approaches, namely (a) associationism/behaviorism—connection among disparate ideas, and between stimulus and response (especially Mednick, 1962), (b) psychodynamic, focused on conscious and unconscious thought (thus inclusive of the psychoanalytic), (c) humanism, focused on intra-individual life forces and motivations, and (d) cognitivism, focused on thinking processes and skills. These two categorizations clearly intersect. They provide frameworks for inquiry into creativity, and a backdrop for understanding creative processes.

Creative Cognitive Processes

Just what are the cognitive processes that yield creative ends? One approach to resolution here is to examine the logic of exceptionally creative people. In one such study, Cross (2002) used phenomenological methods to explore the creative cognitive processes of three exceptional designers from different domains of design, and found some commonality in their approaches including (1) they relied on first principles both in origination and development of concepts (such as adherence to fundamental physical principles or design basics), (2) they explored the problem space in a way that pre-structures or foreshadows the emergence of design (for example, they may give precedence to providing joy to the user), and (3) creative design comes about when there is tension to be resolved between problem goals and solution criteria. Using these areas of commonality, Cross fashioned a model suggesting that exceptional designers take a broad systems approach to design, but they also frame problems in distinctive personal ways that seem to issue from their particular personalities.

Also examining the approach of exceptionally creative people, Csikszentmihalyi (1996) arrived at his conception of *flow,* the optimal state of experience that yields novelty and discovery. From his observation he too arrived at a systems explanation, surmising that creative flow involves feedback that produces enjoyment when novelty occurs. When things are going well in the act of creating, subjects report their behavior to be almost automatic and unconscious. This state of flow seems to be preconditioned by a set of enablers including having clear goals, balancing between challenges and skill, merging action and awareness, and not fearing failure.

While much could be learned about creative processes through examination of the logic of people who are exceptionally creative, it needs to be remembered that creative behavior is not monopolized by the gifted (Guilford, 1950). For example, Chomsky (1957) called attention to the routine, flexible use of language among humans. Ward, Smith and Finke, (1999) contended that human ability to construct an array of concepts from otherwise discrete experiences is evidence of our "generative ability." Generative ability includes cognitive acts such as retrieval of existing structures from memory, forming simple associations, transforming existing structures into new ones, analogical transfer, and metaphorical thinking. Such abilities, along with conceptual combination, divergent thinking, and productive thinking, are processes that must become better understood in the technology education community as modes of reasoning associated with creative production. Next, these cognitive processes identified here are briefly examined.

Metaphorical Thinking.

Metaphors are powerful creative tools that allow comparison and categorization of materially unlike entities. They involve mapping across conceptual domains, from a source domain to a target domain (Glucksberg, Manfredi & McGlone, 1997; Lakoff, 1993). An example of metaphorical thinking would be the characterization of the Internet as an "information highway." By facilitating description of new situations through reference to familiar ones, metaphors allow conceptual leaps (e.g., Glucksberg & Keysar, 1990). Metaphors bring into play the right side of the brain, which, different from the logically oriented left side, is holistically oriented, supportive more of the strategic than the tactical, and can facilitate dealing with ambiguity. They function at the executive level, subsuming analogies, and relying on the principle of association to facilitate connections among unlike entities (e.g., Genter & Jeziorski, 1993; Sanders & Sanders, 1984).

Metaphorical thinking exercises can be employed as auxiliary activities supportive of design teaching and learning in technology education. Teachers can provide students with prototypic examples of metaphors, then require them to conceive of as many as they can.

Analogical Thinking

An analogy is a special type of metaphor, its signature being a structural match between two domains (Gentner, Brem, Ferguson, Wolff, Markman, & Forbus, 1997). Analogical thinking involves mapping of knowledge from a base domain to target domain to facilitate one-to-one correspondence. An example would be the connection that Rutherford made between the solar system and the hydrogen atom (Gentner & Jeziorski, 1993), or the parallelism that can be drawn between electric current flow and fluid flow. Analogies are tactical; they make possible the solution of a given problem by superimposing upon it the solution to a problem in a different domain (e.g., Gick & Holyoak, 1980). Thus, airplane flight is analogous to the flight of birds. The spider-web has been the basis of design of architectural structure.

Analogical thinking can conceivably aid design reasoning in technology education classrooms, if teachers are able to draw upon particular technological examples where the inspiration for the design came from nature. Students can readily see the similarity between airplanes and birds. They can learn about the stability of structures by studying the foundation of trees. If they are encouraged to conceive of many more such analogical examples, students will thereby be engaging in the kind of thinking that is required for solving design puzzles.

Combinatorial Creation

Combinatorial creation is a design process in which two or more concepts or entities are combined to yield an entirely new product (Wisniewski, 1997). It is a creative approach explainable by association or composite theories. In nature the combination of hydrogen and oxygen yields water, a unique product with properties different from the component gases (Ward, Smith, & Vaid, 1997). In the commercial world, the combination of two dissimilar products can yield a composite novel result. For example, metals are made more resilient by alloying. A kite combined with water skis provide a novel recreational vehicle. Seeing the novel combinatorial possibilities inherent in two dissimilar objects requires creative insight, and uncovering how people reason about combinations can be a way to gain understanding of the nature of creativity.

In the technology education classroom, combinatorial activities could become part of the repertoire of the teacher. Students could be asked to arrive at designs that are the product of two existing objects or products. They can be given thought exercises, the aim of which could be to imagine new products that can materialize from combinations of existing ones.

Divergent Thinking

Divergent thinking was included by Guilford (1959) as a facet of his structure of intellect. In this work, Guilford proposed that intellect was composed of thought processes or *operations*, *contents* that are the raw material of operations, and *products* that are outcomes of operations. Divergent thinking and convergent thinking were included among operations. Convergent thinking yields fully determined conclusions drawn from given information. It is associated with general intelligence. *Divergent thinking yields a variety of solutions to a given problem*. Guilford (1967) found divergent thinking to be composed of four factors, *fluency*, ability to produce many ideas; *flexibility*, producing a wide variety of ideas; *originality*, producing novel ideas; and *elaboration*, adding value to existing ideas. Divergent thinking is believed to be a characteristic of creative minds (e.g., Baer, 1993; Wakefield, 1992). In technology education it squares with approaches to the teaching of design that require students to brainstorm and to generate multiple solutions to problems.

Productive Thinking

Productive thinking is creative behavior as characterized by Gestalt theorists. Wertheimer (1968) applied it to problem solving, suggesting that structural features of the problem set up stresses in the solver, and that as these stresses are followed up they cause the solver to change his/her perception of the problem. The problem is restructured, peripheral features are separated from core features, and solutions emerge. Duncker (1945) suggested that the act of problem solving involves reformulating the problem more productively. The problem solver must invent a new way to solve the problem by redefining the goals and approaching the final solution incrementally via a succession of insights. He found that *insight* occurs in problem solving only when the solver is able to overcome a mental block, especially that induced by prior knowledge. If the solver thinks of using an object only in the habitual way, where a novel approach is required, creativity will be blocked. He referred to this experience-induced impediment to creativity as "functional fixedness." If one is accustomed to seeing a box used as a container, one may have difficulty seeing the same box as a platform (see Mayer, 1995).

Productive thinking in the technology education classroom would require students to restate or restructure problems in ways that make it easier for them to begin to see solution prospects. As students deconstruct problems, discarding aspects that are not germane to the solution, they are drawn closer to solutions. Students could be provided "thinking outside the box" exercises that require them to consider multiple uses to which everyday objects or devices can be put.

Schooling and Creativity

Schooling is an important aspect of the development of creativity in children. Support for such development can begin with a curriculum that takes student interest and individual differences, including thinking styles, (Sternberg, 1990) into account. Especially, the curriculum must account for the multiple intelligences among students (Gardner, 1999). We can gain insight into what creativity enhancement through the school curriculum might entail by setting forth the six resources identified by Lubart and Sternberg (1995) as being critical to creative performance as a framework. These "resources" are (1) problem definition or redefinition, (2) knowledge, (3) intellectual styles, (4) creative personality, (5) motivation to use intellectual processes, and (6) environmental context. How can these resources be engaged in classrooms?

While students with exceptional creative talent would benefit from curricula that deliberately include a creativity-oriented component, all children stand to benefit when such an approach is taken. Cropley (1997) contended that the inculcation of creativity should be a normal goal of schooling, with the aim being to help all students attain their creative potential. Children should be helped to achieve effective surprise in their work. He outlines a framework of ideas around which a creativity-focused curriculum can revolve—one that overlaps with Lubart and Sternberg's resources approach. It includes provision of content knowledge, encouraging risk taking, building intrinsic motivation, stimulating interest, building confidence, and stimulating curiosity (Cropley, p. 93). As can be seen here, creativity enhancement must address factors that are *internal* to the student, such as personality and intellectual disposition, as well as factors that are *external,* such as curricular, social, and environmental.

Domain knowledge features are a key prerequisite of creative productivity in the schemas offered by both Lubart and Sternberg (1995) and Cropley (1997). There is strong evidence in the research literature indicating that a fund of domain knowledge is imperative for creative accomplishment (e.g., Simonton, 1988; Csikszentmihalyi, 1996). Cropley (1997) contended that providing such knowledge is one important way in which schools can foster the development of creativity. Lubart and Sternberg (1995) write that knowledge of the state of knowledge in a domain prevents attempts to reinvent the wheel. Nickerson (1999) offered the view that the importance of domain-specific knowledge in the forging of creativity is underestimated. He argued that across a wide front of domains, including the arts, mathematics, and science, acquisition of a solid knowledge base is a precursor of exemplary creativity. He wrote:

> One cannot expect to make an impact in science as a consequence of new insights unless one has a thorough understanding of what is already known, or believed to be true, in a given field. The great innovators of science have invariably been thoroughly familiar with the science of their day. Serendipity is widely acknowledged to have played a significant role in many scientific discoveries; but it is also acknowledged that good fortune will be useful only to one who knows to recognize it for what it is. (p.409)

It is necessary to offer a caveat with respect to the importance of domain knowledge and it is the contention that prior knowledge could sometimes impede creative behavior. As Lubart and Sternberg (1995) pointed out, high levels of knowledge can actually stymie creativity. Dunker (1945) referred to this possibility of the problem of "functional fixedness" where one is unable to break away from normative usage of an item. Weisberg (1999) spoke of the tension between knowledge and creativity, suggesting a U-relationship between the two that acknowledges both positive and negative transfer of knowledge. Still, the fact that prior experience or knowledge could conceivably depress creativity is more a caution than an argument against domain-knowledge acquisition as a basis of expertise and creativity. Schools must provide children with the foundational knowledge supportive of creative insight.

Beyond provision of domain knowledge, schools can enhance the creativity of children if classroom environments support and facilitate risk taking, problem posing, individual learning and thinking styles, and intrinsic and extrinsic motivation (Jones, 1993; Jay & Perkins, 1997; Lubart & Sternberg, 1995; and Cropley, 1997). Some school contexts are more supportive of creative behavior than others, and the factors that can militate against creative behavior may be both internal and external in character (Jones, 1993). For example, low self-esteem could inhibit creative effort (e.g., Hennessey & Amabile, 1988). The external environment can dampen creativity if it does not reward creative behavior, or if it deliberately suppresses it.

Creativity can be enhanced in the curriculum by providing students more opportunity for problem finding, as a precursor to problem solving (e.g., Moore, 1993). Problem finding has not been given as much prominence in technology education as problem solving (see Lewis, Petrina, & Hill, 1998). France & Davies (2001) show how questions can be a part of a collaborative process in community-based problem solving. Wertheimer (1968) drew attention to the importance of problem-finding as a marker of creativity, contending that "Often in great discoveries the most important thing is that a question is found.

Envisaging, putting the productive question is often more important, often a greater achievement than solution of a set question…" p.141. Problem finding refers to the way that a problem is conceived and posed, and includes the formulating of the problem statement, periodic assessment of the quality of the problem formulation and solution options, and periodic reformulation of the problem (e.g., Getzels & Csikszenthmihalyi, 1976; Jay & Perkins, 1997). Mumford, Reiter-Palmon and Redmond (1994) wrote that problem construction contributes to creative problem solving, and that it is a predictor of real world creativity. Runco and Chand (1994) examined how individuals decide whether problems are worth pursuing, finding that metacognitive evaluation is a key to their method.

Creativity and Technology Education

Technology education is a special place in the school curriculum where creativity can be fostered uniquely. Indeed, the subject is premised upon human creativity—on the ingenious ways in which from the time they stood upright, human beings have devised ways and means to deal with problems that beset them in daily existence to assure their very survival, and ultimately to improve the quality of their lives. In the long march across time from river crossings in canoes, to space crossings on rocket-powered ships, human beings have along the way systematically relied upon their creativity to overcome existential obstacles, and with each advance have yielded and stored technological knowledge upon which even further advance could be made.

Early forms of the subject tended to focus upon rehearsing basic overt technological processes, such as tool use, and the making of artifacts. As the subject has progressed, there has been a retreat from this essentially instrumental focus toward one where children are taken behind the scenes of human advancement and presented with hurdles that can be overcome only through their creative design. This shift of the subject to an earlier place in the stage of the process of technological creation, where things are unsettled and there is no single right answer, has made the subject almost ideally suited to uncovering dimensions of the creative potential of children that would remain hidden in much of the rest of the curriculum. While the American content standards in science now include technological design as an area of study (see National Research Council, 1996), the long tradition of technology education gives the latter subject a much greater claim to this content.

Design

The strong design focus of the American Standards for Technological Literacy offers opportunities for teaching to enhance creativity. What makes design so specially suited to the inculcation of creativity in children is its open-endedness. There is more than one right answer, and more than one right method of arriving at the solution. The ill-structured character of design requires that students resort to divergent thought processes and away from the formulaic. As they do so, their creative abilities are enhanced. But despite the potential here, there are indications in the literature that we still have some way to go before creativity becomes a more central feature of the teaching of design in the United States and elsewhere. For example, McCormick and Davidson (1996) cautioned that in teaching design, British teachers were giving precedence to products over process. Others observe that technology teachers in Britain were pursuing a formulaic line when teaching design, comprised of stages that were often contrary to the natural design tendencies of children (e.g., Chidgey, 1994; Johnsey, 1997).

This tendency toward teaching design as a process that proceeds through definable stages is evident in the United States as well, noticeable in the Standards for Technological Literacy (International Technology Education Association, 2000), which states that:

> The modern engineering profession has a number of well developed methods for discovering such solutions, all of which share common traits. First, the designers set out to meet certain design criteria, in essence, what the design is supposed to do. Second, the designers must work under certain constraints, such as time, money, and resources. Finally the procedures or steps of the design process are iterative and can be performed in different sequences, depending upon the details of the design problem. (p. 90)

Reeder (2001) set forth a set of comparable steps in his description of how industrial design is taught at his university, but included is a conceptual development stage that involves open-ended, divergent thinking.

The problem for the field of technology education in the United States and elsewhere is that the overt description of the stages of the design process, observable when engineers do their work, has become the normative design pedagogy. This stage approach runs the risk of overly simplifying what underneath is a complex process. Teaching design as a linear stage process is akin to arriving at a pedagogy of art by mere narration of the observable routines of the artist. It simply misses the point that design, like art, proceeds from deep recesses of the human mind. To arrive at a pedagogy of design, there is need to get beneath the externals of the process. The key is to recognize design as a creative rather than a rationalistic enterprise.

Roger Bybee, a strong advocate of the new standards for technological literacy, wrote that "Technological design…involves cognitive abilities such as *creativity* (emphasis added), critical thinking, and the synthesis of different ideas from a variety of sources" (Bybee, 2003, p.26). This creative element requires an approach to teaching that gets deeper below the surface.

We are beginning to see interesting deviations from the normative approach to the teaching of design (e.g., Hill & Anning, 2001; Flowers, 2001; McRobbie, Stein & Ginns, 2001; Mawson, 2003; and Warner, 2003. One concept being explored is "designerly thinking" where a constructivist approach to student design approach is taken in an effort to unearth just how students solve problems. Flowers suggested that humor in the design and problem solving classroom can promote divergent thinking. Arthur Koestler (1969) gave credence to humor as an important marker of creativity in his landmark contribution, *The Act of Creation.* Humor in the creativity-oriented classroom is consistent with the view, embedded in leading theories and research, that creativity has an affective dimension—that it thrives in environments in which intrinsic motivation flourishes. Such environments encourage non-conformist thinking and personality types that thrive better in less structured settings (e.g., Eysenck, 1997).

Warner (2003) joins Flowers in pointing out that the tone of classrooms can make a difference in the quality of the creations of children. He argued that to support creativity in technology education classrooms, teachers must be more tolerant of failure. Flowers wrote that "Teachers of design must maintain a classroom culture that promotes successes but embraces the learning opportunities that failure presents" (p. 10). He drew on research suggesting that some kinds of classroom climates, such as those where competition is encouraged or where rewards are offered for performance, actually dampen creativity (e.g., Hennessey & Amabile, 1988).

Earlier in this article, generative cognitive processes such as analogical and metaphorical thinking, conceptual combination, productive thinking and divergent thinking were identified as means by which creative people have arrived at novel products. Such processes should be included in the pedagogic repertoire of technology teachers. They should be taught to students in design classes in technology education, as devices that can be employed in solving design challenges. We see an excellent example of the how metaphorical and analogical thinking can be infused into the teaching of design in the contribution by Reed (2004) on biomimicry; that is, design that imitates nature. Reed showed that many scientists and engineers continue to look to nature as they contemplate designs and that many industrial products (e.g., Velcro) are inspired by nature.

Design pedagogy can benefit from ideas such as biomimicry, as prompts for helping students as they engage in creative search. This pedagogy must also be informed by findings emerging from the creativity research literature, especially from studies in which expert designers articulate the logics that underpin decisions they make and actions they take in the act of designing (e.g., Cross, 2002).

Beyond cognitive strategies that are known to yield novel products are the concomitant factors that support creativity, notably the importance of domain knowledge, problem posing, and problem restructuring. We have learned from the literature that domain knowledge is fundamental to creative functioning (e.g., Cropley, 1997). And yet, this is an area of the design discourse in technology education that receives almost no attention. Creativity cannot proceed in a knowledge vacuum. While there is a place for the teaching of domain-independent design, where the context is everyday functional knowledge, it is necessary that children be challenged with design problems that reside in particular content domains, such as electronics, manufacturing, or transportation. Children are more likely to arrive at creative solutions when they puzzle over such problems if they are first taught the supporting content knowledge.

Though problem posing ability is an acknowledged marker of highly creative behavior (notably Getzels & Csikszenthmihalyi, 1976; and Wertheimer, 1968), it remains an almost neglected aspect of the technology education discourse—a discourse steeped in treatment of problem solving. And yet, as Lewis, Petrina & Hill (1998) argued, using principles of constructivist learning in support, that we should be as interested in the ability of children to find good problems as in their ability to solve problems. There are implications here for how we arrive at design problems in our classrooms. Are those problems teacher-imposed, or do they originate from the observations of our students?

Akin (1994) called attention to the creative potential of problem restructuring for increasing the creative potential of design. Drawing from experiences in architecture he distinguishes between anonymous and signature design, and between routine and ill-defined problems. Ill-defined problems are not bounded by available design standards. They require "the additional functionality of problem restructuring as they cannot be resolved without a framework within which problem solving can operate" (p.18). According to Akin, within problem restructuring resides great creative potential, capable of yielding signature work. This view that problem restructuring engenders creativity is consistent with the concept of productive thinking (Dunker, 1945; Wertheimer, 1968).

There clearly is a need in technology education for a more textured discourse on the teaching of design than currently exists. Problem posing, problem restructuring, analogical and metaphorical thinking, and the use of humor are pedagogical devices that belong in an expanded view of how the creative aspect of design can be realized.

Implications for Technology Education

Unquestionably, the publishing of content standards represents an advance for technology education. This article has offered creativity as the framework for a discourse on design and problem-solving, and as a complementary conversation to that on content standards. In a way, this article constitutes a caution to the technology education community that the subject is still a work in progress, and that there are aspects of it that are not given naturally to rationalistic content-derivation methods. We are at a point where the subject in the curriculum from which technology education increasingly takes its cue is science, with its exactness; but it may be that we can benefit from alliances with other subjects, such as art or music, that have ill-structured aspects, and where students are encouraged to use knowledge not for its own sake, but in support of thought leading to creative expression.

Five kinds of implications for technology education are suggested by the discussion on creativity that has ensued here, namely (a) implications for design/problem solving pedagogy (b) implications for assessment (c) implications for professional development, (d) implications for curriculum theorizing, and (e) implications for research. Each is reflected upon briefly here as the article concludes.

Design/Problem Solving Pedagogy

Despite the centrality of design/problem solving activities to technology education, the field has not made strides in finding proven ways in which these activities can be taught. One explanation for lack of movement here is that insufficient attention has been paid to the role that creativity plays in design/problem-solving. A creativity focus allows for inclusion of a wider array of auxiliary activities into the pedagogic approach—activities in realms of divergent thinking, productive thinking, metaphorical thinking, analogical thinking, and combinatorial creations. Much more needs to be done in technology education to find approaches that are precursors of successful design experiences for children.

Assessment

As with pedagogy, assessment of design and problem-solving activities in technology education is still a fledgling area. A reason is that the field has not worked out measures for helping teachers determine the degree of creativity inherent in students' design-related work. When is the design routine, when middling, and when exemplary? This is an area of need. Technology education teachers have to be able to distinguish between gradations of creativity and to communicate their assessments to students in much the same way that teachers of art and music are able to do in their classrooms. There is a clear need here for an expanded discourse on assessment in the field that includes the challenges inherent in providing feedback to students when the intent is to help them improve their designs.

Professional Development

Pre-service teacher education programs in technology education ordinarily do not include coursework on creativity. Thus, most teachers do not have preparation that is sufficient enough to allow them to inject creativity into their teaching. Teachers may introduce design/problem solving activities into their teaching, but the competence they bring to the classroom is more in the realm of the technical than the aesthetic. There is a clear need here for professional development activities aimed at helping teachers see possibilities for introducing creative elements into the curriculum, and into instruction.

Curriculum

In the rich literature on technology education curriculum, creativity is often implicitly included, especially where the focus is on design and problem solving. But there is an absence of explicit treatment of the topic. This clearly is a shortcoming, made more telling by the new focus in the standards, on design. Creativity in all of its facets, and as it relates to technology education teaching and learning, needs to be a more deliberate focus of the technology education curriculum literature.

Research

Creativity has strong claims toward being a foundational area of research in technology education. Such research can address a host of pressing needs, including methods of assessing creative performance, auxiliary instructional activities that are good precursors of student creative performance, professional development activities that improve teacher competence in teaching design/problem solving, and strategies employed by students as they complete creative tasks.

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East Meets West: What Americans and Hong Kong People Think About Technology

Kenneth S. Volk and William E. Dugger, Jr.

A few years ago, Rose and Dugger (2002) published the results of a public opinion poll on *What Americans Think about Technology*. Sponsored by the International Technology Education Association (ITEA) and conducted by the Gallup Organization, this ITEA/Gallup poll revealed many things about the public's understanding and attitudes about technology, as well their ideas about technology in the school curriculum. Referencing the comprehensive *Standards for Technological Literacy* (ITEA, 2000), a project that used experts to identify the content for technology education, an objective of the ITEA/Gallup poll was to determine if the public's perception of technology is congruent with that of the experts. Clearly, given the thoroughness and credibility of the *Standards* along with its expected potential to influence technology education policy, direction and, content, an examination of public opinion was seen as being vital in determining the degree to which expert rhetoric matched public reality and expectations.

Similarly, Hong Kong is now going through dialogue and critical self-examination about technology education. In a departure from practice at the time, Hong Kong's Curriculum Development Council (2000) in their document *Learning to Learn*, recognized the importance of technology and specifically identified Technology Education as one of the eight necessary Key Learning Areas (KLA) for all Hong Kong students to acquire from the six primary grades through the lower three secondary grades. The CDC also applied a broad definition of technology as being "the purposeful application of knowledge, skills, and experiences in using resources to create products or systems to meet human needs." The impact of ITEA's work and perspective was evident in references made to it in the *TEKLA Curriculum Guide* (CDC, 2002) that subsequently followed. Similar to ITEA's *Standards*, the *Guide* was developed by academics, professionals from related fields, and other experts in order to help realize the recommendations made in the *Learning to Learn* document. The *Guide* included the framework, learning objectives, assessment practices, as well as exemplars for technology education.

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Considering that technology transcends international borders, many socio-economic parallels exist between the US and Hong Kong, and both societies recognize the imperative of having a technically literate citizenry, a study was conducted on what Americans and Hong Kong people think about technology. Given the commonalities between the US and Hong Kong, this study would seek to ascertain if there is a similar understanding and knowledge of technology, as well similar concepts and priorities about technology education. In so doing, this study would add to the body of knowledge about cross-cultural, cross-country comparisons relating to technology, as well as the appropriateness of generalizing technology education curriculum in a global context. To facilitate making comparisons, the study conducted in Hong Kong used a similar instrument to that used in the ITEA/Gallup poll. This invitation to conduct additional research using the ITEA/Gallup poll was encouraged by ITEA (Rose and Dugger, 2002). In this manner, corresponding data between the US and Hong Kong could be analyzed for significance and conclusions drawn.

The US and Hong Kong Context

Before making any comparisons between the results of the study done in Hong Kong with the one done in the US by ITEA/Gallup, caution needs to be raised about the appropriateness of using data from two studies for comparisons, especially between cultures. Noah's (1984) critique of the comparative education research cited ethnocentrism among the most notable misuse of such comparisons. This relates to looking at the world primarily from a point of view of the observer's own culture and values. In this regard, using a survey designed for a US study may influence and limit comparisons, as not only are the respective cultures and values obviously different, so are facets of the economies, education systems, and politics.

Given the increased sophistication of technology and increasing human interaction with technological products throughout the world, examining such issues as they relate to the public's perception of technology and education may be appropriate. Noah recognized the importance of technology on all cultures many years earlier, when writing with Eckstein in their classic *Toward a Science of Comparative Education* (1969), they described the modernization of developing countries such as India. They stated: "the most important means of modernization may be the increasing availability of automobiles, bicycles, water pumps, and so forth" (p. 116). According to the authors, counting schools and the number of students was not enough, for the "informal effects" of Western technology also needed investigation.

Given this caution, there are examples where cross-cultural comparisons have been successfully undertaken, some with the US serving as a benchmark. For instance, the Trends in International Mathematics and Science Studies (TIMSS) "resulted from the American education community's need for reliable and timely data on the mathematics and science achievement of our students compared to that of students in other countries" (National Center for Education Statistics, 2004). The Program for International Student Assessment (PISA), sponsored by the Organization for Economic Co-operation and Development (OECD), followed the TIMSS study and was an international assessment designed to help understand how the performance of students in subjects such as science compares to that of peers in OECD and non-OECD countries. Another example of cross-cultural comparisons that specifically related to technology education was the Pupils' Attitudes Toward Technology (PATT) studies conducted over the past 20 years. Led by Dr. Marc DeVries at Eindhoven University of Technology, thirteen PATT Conferences have been held. Although many PATT conference papers examined cross-national comparisons, such comparisons were not without problems and limitations (Volk and Yip, 1999).

Despite the obvious differences in culture, history, language, government structure, and population density, there are many similarities that make the United States and Hong Kong interesting and appropriate to compare. Some of these similarities relate to the use of technology, employment rates, annual income, and educational attainment. Even their respective Gini Coefficient ratings reflect the growing unequal income distribution facing both populations, with both greater than most developed European nations (United Nations, 2004). Table 1 shows selected demographic indicators obtained from sources such as the Asia Development Bank, the Hong Kong Census and Statistic Department, the United Nations, US Department of Labor, and the World Bank.

The table of demographics also points out several differences between the US and Hong Kong. For example, given the expense of living in Hong Kong and the current difficult economic times and atypical high level of unemployment, the birth rate has dropped precipitously and is considerably lower than in the US. Hong Kong's past manufacturing base is now much smaller, with industry having moved across the border into China. Hong Kong's spending per student is also considered low, especially since the government is not obligated with other expenditures such as military defense.

As far as the use and impact of technology in Hong Kong and United States, many parallels can be drawn. One obvious area is the confusion over technology education (TE) and educational technology (ET) - the latter going under names of information technology (IT), information communication technology (ICT), computer studies (CS) and others. Petrina (2003) addressed this confusion and pointed out the attempts by organizations such as the International Technology Education Association (ITEA) and the International Society for Technology in Education (ISTE) to maintain differences despite the great overlaps in content, ideology, and standards. Dugger and Naik (2001) also raised similar concerns and tried to explain the differences between technology education and educational technology. However, in acknowledging the problem in misconceptions that exist even for educators, the authors challenged that technology education teachers must be the ones to educate others.

Table 1
US and Hong Kong Demographics

	US	HK
Literacy (percent ages 15+)	97.2	94.0
Unemployment rate (percent)	5.3	6.8
GDP per person (US$1,000)	32.8	25.6
GDP - Composition by sector (percent)		
Agriculture	2.0	0.1
Industry	18.0	14.7
Services	80.0	85.2
Current spending per student (% of GDP)	4.9	2.9
Starting teacher salary (per month, US$1,000)	2.5	2.1
Gini Coefficient*	0.4	0.4
Cellular telephone subscribers (percent of adult population)	62.0	87.2
Internet users (percent of population)	54.0	48.4
Median age of first marriage (female)	25.0	28.0
Life expectancy at birth (years)	80.5	81.5
Births per 1,000 population	14.0	6.8
Crime rate (per 100,000)	730.0	207.0

* The Gini Coefficient, also known as the index of income distribution, is used to measure income inequality. A Gini coefficient of 0 means that income is equally distributed among the population, while a value of 1 means essentially one person has all the income while everyone else has none.

Confusion also exists in Hong Kong about what constitutes technology, with different public groups offering different emphases and/or meanings. For example, the Hong Kong Education Commission's (1999) *Education Blueprint for the 21st Century* report was rife with references to technology, but they were almost totally related to information technology. This was in contrast to statements from other public bodies such as the Curriculum Development Council (2002) and Commission on Strategic Development (2000) that regarded technology in a broad sense. In this regard, comparing US and Hong Kong general public opinion about technology education is warranted, especially given that both have publicly stressed the need for technology education.

One last aspect which ties the two studies and cultures together is the expected change by 2010 in the Hong Kong school structure from a "British system" to one that more closely resembles an "American system" (Education Commission, 2000). This restructuring will have students finishing secondary school after grade 12, instead of grade 13. University bachelor degrees will then correspondingly increase in time from three years to four. With this expected common education structure, perhaps both cultures can learn from each other's concepts about technology and technology education.

Methodology

Both the US and Hong Kong studies used telephone interviews to obtain survey results. The Hong Kong poll was completed in early 2004 and used questions from the first ITEA/Gallup Poll (Rose & Dugger, 2002). The second US ITEA/Gallup Poll (Rose, Gallup, Dugger & Starkweather, 2004) was conducted after the Hong Kong poll, with some additions and deletions made to the original questions. Since the Hong Kong Poll was conducted between the two ITEA/Gallup Polls, the comparisons made between Hong Kong and the US use data that were compatible and/or most current.

Obvious concerns arise about the appropriateness of using an existing questionnaire from one culture and translating it into another. As noted by Behling and Law (2000), the lack of semantic equivalence across languages, lack of conceptual equivalence across cultures, and the lack of normative equivalence across societies may be problematic. They point out measures that will help ensure reliability, validity, and contextual use of words in the source language. Based on their recommendations, a modified direct translation was used for this study, whereby a panel of experts made independent checks on the work of the original translator. In this procedure, the panel (a) reviews the items and reacts in writing, (b) shares their comments with one another, and (c) meets to consider the points made and make recommendations. For translating and preparing instructions, recommendations from Behling and Law were also taken into consideration to ensure proper words, grammatical forms, and sentence structure follow cultural contexts.

The first step for using the ITEA/Gallup instrument in Hong Kong was to examine each item for appropriateness and relevance. An initial independent review by three lecturers in Design & Technology (D&T) at The Hong Kong Institute of Education determined two items required modification. One question included a specific definition for technology, so the exact definition used in the TEKLA, rather than ITEA's was considered more appropriate. Another question asked if the individual interviewed could explain how a home heating system works. To match the Hong Kong context, this item was changed to ask how an air conditioner works. After this initial review, the D&T lecturers then translated the instrument into the Cantonese dialect of Chinese used in Hong Kong. Careful attention was given to words such as "Technology", with the Chinese version of the *TEKLA Curriculum Guide* used as reference. From this translation by D&T lecturers, three lecturers in the Chinese Language Department were sent the original and Chinese versions for further comment and refinement.

Based on an estimated adult population of 5,008,886 (HK Census & Statistics Dept, 2003), the sample size required for the Hong Kong study would be approximately 750 (Gall, Gall, and Borg, 2003). This number would be sufficient for a margin of error of plus or minus four percentage points and at the 95% confidence level. This sample size was similar to both the first and second ITEA/Gallup Polls, with sizes of 1,000 and 800 used respectively. The

ITEA/Gallup poll also maintained a 95% confidence level with a margin of error set at plus or minus four percentage points.

Datacap Computer Solutions Ltd, a data capturing firm experienced in telephone interviews for many Hong Kong government projects, was used to conduct a two-stage telephone interview of 750 adults age 18 and older. Stage One involved households selected in accordance with the 2003 white page database issued by PCCW, the largest telephone provider in Hong Kong, with the telephone number randomly selected by CATI telephone survey system. Stage Two involved the random selection of household members with a base on the nearest birthday. The ITEA/Gallup Polls also used a random selection of households and a multiple stage approach to select one person in the household.

Table 2 provides details of the sample composition for the Hong Kong and second ITEA/Gallup poll. Differences in sample composition were noted for age and education, with the Hong Kong sample being younger and with less education. As far as the Hong Kong population's level of education, it was only in 1978 that Primary 6 school leavers were guaranteed a place in secondary school. Combined with the examination-driven system of progression and the limited number of places in university programs, the Hong Kong sample matched the education level reflected in the general population (Hong Kong Census and Statistics, 2004). It appears the age of the US ITEA/Gallup sample quite closely reflected that in the US (US Census Bureau, 2004), while the sample for Hong Kong had a higher proportion of young adults (32.4%) than in the general population (27%).

Table 2
Hong Kong and US Sample Comparison

	HK(%)	**US(%)**
Gender		
Male	45.9	48.6
Female	54.1	51.4
Age		
18-29	32.4	17.7
30-49	49.0	41.7
50+	17.3	39.7
Missing	1.3	0.9
Education		
Less than high school	25.6	9.3
High school graduate	33.4	27.9
Trade/Two-Years College	4.8	33.1
College Graduate or more	26.2	29.6
Missing Data	0.0	0.1

As the information gained from the telephone interview was opinion-based, and since such surveys are about what people think and what it prepared to support or not support, percentages were used to analyze the data. Chi-square was also used to examine whether there was some relationship between US and Hong Kong poll results. Babbie (1999) and Baker (1999) noted the use of chi-square as being one of the most widely used tests for statistical significance in the social sciences when the variables are nominal or ordinal in measurement. Bernard (2000) even explained how chi-square can be used to make comparisons across complex tables with several sub-variables. All authors cautioned that chi-square does not measure the strength of the relationship.

Findings and Discussion

Data from the first and second ITEA/Gallup poll were compared with the Hong Kong poll about what adults think about technology. With the large number of questions included in each poll, only selected items were presented in detail for this discussion. The public's responses to some of the questions were described in more general terms. In the following discussion, when 2004 ITEA/Gallup data were available, they superseded the 2002 ITEA/Gallup data.

Understanding Technology

The first series of questions related to the public's understanding of technology. The response to the first question indicated Americans placed a significantly greater importance on being able to use and understand technology [$\chi^2(2, N=2036)$ 394.087, $p<0.01$]. Table 3 shows that while over two-thirds of Americans had this opinion, less than one-third of Hong Kong people viewed this item as being "very important." It was also surprising that over six percent of Hong Kong people identified using or understanding technology as being "not very important."

Table 3
Just your opinion, how important is it for people at all levels to develop some ability to understand and use technology? Would you say it is:

	HK %	US '04 %
Very important	28.9	73.8
Somewhat important	64.2	23.6
Not very important	6.3	0.4
Not at all important	0.4	1.5
Don't know/refused	0.2	0.7

The next question was open-ended, asking people what comes to mind when they hear the word "technology." The Hong Kong responses were entered into a database, then grouped under categories similar to those used in the US study. Table 4 compares the responses to this open-ended question.

Table 4
When you hear the word "technology, what first comes to mind?

	HK %	US '04 %
Computers	47	68
Advancement	7	2
New Inventions	7	1
Electronics	5	5
Information	4	0
Science	3	1
Space	3	1
Things That Make Life Easier	3	0
Machinery	2	1
Internet	1	2
Education	1	1
Others	19	18

Rose et. al. (2004) noted that for Americans, "computers have no rival in the public's mind as emblematic of 'technology'" (p.2). With over two-thirds of the US sample saying "computers," this claim is easily substantiated. In contrast, it appears Hong Kong people have a much broader view of "technology," with less than half providing "computers" as their definition. Compared to the US polls, respondents in the Hong Kong study were more likely to use descriptors that transcend the physical hardware of technology, with terms such as "advancement," "new inventions," and "information" used. Although the ITEA/Gallup data did not distinguish between urban and rural participants, it is possible the fast-paced and technologically stimulating environment that is ever-present in a compact and quickly-changing metropolitan area such as Hong Kong would produce a wider perception of technology.

After the open-ended response, people were then asked to choose between either a specific broad definition of technology or one that narrowly-defined technology as computers and the Internet. For both studies, the broad definition provided was the one used by their respective professions. For example, the Hong Kong poll used the TEKLA definition of technology, "the application of knowledge, skills, and experiences in using materials to create products to meet human needs," while the US poll used an ITEA definition of "changing the natural world to satisfy our needs." As indicated in Table 5, two thirds of Hong Kong people agreed with the broad definition, which was in stark contrast to the US response, where a majority had a narrow definition of technology [χ^2(2, N=2376) 183.177, $p<0.01$].

Table 5
Which more closely fits what you think of when you hear the word "technology"?

	HK %	US '01 %
Computers and the Internet	34	63
The application of knowledge..... Changing the natural world	66	36
Don't know/refused	-	1

The results from this question echo the responses given earlier in Table 4, with Hong Kong people applying wider definitions for technology. Even with limited efforts to educate the public about the elements of technology education through Key Learning Area promotional material, Hong Kong people appear to be naturally more accepting of the profession's definition. Given the challenges in both the US and Hong Kong to convince the public about the need for technology education, it appears Hong Kong may potentially be more successful, as many of the citizens can already "talk the talk."

Table 6 shows the results of the public's capability to understand and use technology. It appears US citizens have a higher perception of their ability to understand and use technology [χ^2(2, N=2397) 579.239, p<0.01]. When asked to respond to one of four qualifiers provided, 75 percent of Americans indicated "to a great extent" or "to some extent", while only 24 percent of Hong Kong people indicated these characteristics. Caution needs to be made about the response to this question, as a specific definition of technology was not included. It is possible, based on the results seen in Table 5, that the US public was responding to a narrow "computer" definition, while Hong Kong people were responding to their wider definition. For example, in the US study, 90 percent of 18-29 year olds responded "to a great extent" or "to some extent", while 57 percent of those 50 and older had this perception. For Hong Kong, the difference was much smaller, being 31 percent and 26 percent respectively.

Table 6
To what extent do you consider yourself to be able to understand and use technology?

	HK %	US '01 %
A great extent	2	28
To some extent	22	47
To a limited extent	66	20
Not at all	10	5
Don't know/refused`	-	-

Knowledge and Attitudes of Technology

Several questions asked respondents about their knowledge of and attitudes about technology. The first question asked participants about their attitude toward technology in their everyday life. Hong Kong people seemed somewhat more ambivalent than Americans about the value of knowing more about technology, with one third (37%) responding they do not care about how things work. For those in the US, only one quarter (24%) had this lack of interest. There were significant differences between the US and Hong Kong answers to this question [χ^2(2, N=1401) 61.908, p<0.01]

Another series of questions asked about the effect of technology and how much input the public desired into the decisions being made about technology. Americans identified "the society" (67.4%) as the most important effect of technology, while Hong Kong people said "the environment" (62.4%) [χ^2(2, N=2367) 610.417, p<0.01]. Hong Kong's response might be reflecting the growing concern about worsening air and water pollution due to the rapid industrial expansion and lack of stringent environmental controls across the border into China (Civic Exchange, 2004). For decisions about items such as the designation of neighborhood community centers, where to locate roads in the community, the development of fuel-efficient cars, and genetically-modified foods, Americans expected to have significantly more input into the decisions. Hong Kong's relatively passive response may be an influence of its limited democratically elected government and Confucian heritage (Tsang, 2004) which encourages an acceptance of hierarchical authority.

The next two series of questions showed significant differences in the US and Hong Kong's understanding and knowledge of technology. Table 7 shows the significant differences of whether individuals could explain different technologies to a friend. With all items, Americans were much more confident about explaining technology, perhaps being less-humble than Hong Kong people. Considering the relatively simple operation of a flashlight, it was somewhat surprising that only 30 percent of Hong Kong people were confident

Table 7
Let me ask you if you could explain each of the following to a friend, just answer "yes" or "no". (% yes answers provided)

	HK	US '01	χ^2 (df=2) p<0.01
How a flashlight works	29.9	89.5	(N=2358) 887.910
How to use a credit card to get money out of an ATM	63.4	89.0	(N=2276) 220.331
How a telephone call gets from point A to point B	48.0	64.5	(N=2173) 57.757
How an air conditioner (home heating system) works	53.1	70.0	(N=2329) 82.838

enough to explain how one works. The findings from this item suggest limits to this type of survey question, in that the depth of explanation was not ascertained, nor was the actual need for individuals to know the theory and operation of these particular technologies established.

The public was then asked questions about how specific technologies worked and to answer "true" or "false." Table 8 compares the US and Hong Kong responses, with the percentage of those providing the correct answer provided.

Table 8
Tell me if each of the following statements is true or false (% correct answers provided)

	HK %	US '01 %	X^2 (df=2), p<0.01
Using a portable phone in the bathtub creates the possibility of being electrocuted	57.8	53.0	(N=2306) 4.467
FM radios operate free of static	46.0	26.5	(N=2156) 72.303
A car operates through a series of explosions	61.8	84.4	(N=2218) 134.046
A microwave heats food from the outside to the inside	45.1	62.9	(N=2311) 63.495

The results for this section of questions were split, with each group having more correct for two items. However, none of the answers seemed convincing for either the US or Hong Kong population. This finding seems to concur with those noted by Pearson and Young (2002) in their review of the 2001 ITEA/Gallup poll, that even though many replied earlier in their self-assessment that they were able to understand and use technology (see Table 6), the lack of knowledge made such self-ratings "superficial" (p. 65).

Technology and Education

The last series of questions concerned the study of technology, and how it should be included in the school curriculum. Those polled were asked about a potential shortage of qualified technical people and what their respective governments should do. Hong Kong people had a much more open immigration position than those from the US. With the established and historical practice of expatriates coming to work in Hong Kong, this significant difference [χ^2(1, N=2003) 66.503, p<0.01] was not that unexpected.

Table 9
When a shortage of qualified people occurs in a particular area of technology, which of the following solutions would you feel is the most appropriate course of action for the government to take?

	HK %	**US '04 %**
Bring in technologically literate people from outside Hong Kong (US)	15.8	5.0
Take steps through our schools to increase the number of technologically literate people in Hong Kong (US)	84.2	95.0

When provided with the broad definition of technology (… to meet human needs), those polled were asked if a study of technology should be included in the school curriculum (see Table 10). Overwhelmingly, both samples strongly supported the inclusion of technology in schools. However, when those who said it should be included were asked if it should be a separate subject or combined with other subjects, there were significant differences [$\chi^2(1, N=2002)$ 209.119, $p<0.01$]. Hong Kong people preferred it as a separate subject by a two to one margin, possibly reflecting the culture of public examinations (Kwong, 1997; Sweeting, 2004).

Table 10
Using a broad definition of technology as "the purposeful application of knowledge, skills and experiences to create products to meet human needs", do you believe the study of technology should be included in the school curriculum or not?

	HK %	US '01 %
Yes	97.6	97.4
No	2.4	2.6
Asked of those saying it "should be included in the curriculum" Should the study of technology be made a part of other subjects like science, math and social studies, or should it be taught as a separate subject?		
Part of other subjects	31.6	63.7
As a separate subject	68.4	36.3
Asked of those saying "separate subjects" Should the subject be required or optional?		
Required	38.3	50.7
Optional	61.7	49.3

The responses from the US and Hong Kong were also different when respondents were asked if a study of technology should be required or optional [χ^2(1, N=21073) 16.630, $p<0.01$]. The US response was equally divided on this question, but Hong Kong people suggested technology education should not be a required subject.

Implications

The findings from this study suggest that given the universals of technology, the many socio-economic parallels, and common education imperatives stated on the need for technology education, there exists many differences in US and Hong Kong people's understanding and attitudes about technology. Their response to how technology education should be included in the school curriculum was also dissimilar.

In general terms, Hong Kong people had a concept of technology that included more than "computers" and tended to accept the broad definition of technology presented by their technology educators and government position papers. This could suggest that the technology education profession in the US will have a more difficult time in trying to educate the public about the subject, given the lack of common definition and understanding about what actually constitutes "technology". This is not to imply that it will be easy in Hong Kong, for impediments also exist. However, if nearly two-thirds of Americans do not equate technology as being more than computers and the Internet, it will be very difficult to convince them about the need for a subject that is more encompassing.

Regarding each population's knowledge and attitudes, Hong Kong people seemed less interested in knowing more about technology as well as being part of the decision-making process. Americans perhaps are more accustomed to participatory stances, such as their historical input into educational matters, i.e., local boards of education, and their participation in a democratic government is established and expected (Westheimer and Kahne, 2004). This might suggest that if the technology education profession in the US could be more successful in convincing the general population about what is meant in a broader concept of "technology" and correspondingly that technology education should be a part of the curriculum, change may occur easier. This is because top down education mandates and initiatives are rarely successful without the understanding and support of the local community, both of which are necessary in order to accomplish reform (Fullan, 2001).

The US and Hong Kong's perceived knowledge about technology and their less than convincing answers to specific questions about technology also indicates potential problems. The higher confidence in their ability suggests that what they already know or have learned about technology may be sufficient, at least in their minds. For educators trying to convince a somewhat contented public that they need to know more, or that their knowledge about technology is lacking, may prove a daunting task.

Extrapolating from the data on the public perception about technology and education, it would be difficult to claim that either the US or Hong Kong population would support a required separate subject of technology. Although both samples supported the study of technology education, as suggested in a broad definition (see Table 10), their desire to have it as a separate subject and/or as a required subject was tepid. With 68 percent of Hong Kong people indicating technology should be a separate subject, but only 38 of them saying it should be required, it could be inferred only 26 percent of the total population would support it as a separate required subject, while the number would be less than 20 percent for the US. For Hong Kong, a lack of support currently exists in schools, with only 61 percent of secondary schools offering the broad technology subject of Design & Technology, while 100 percent offer narrow technology subjects in computers (Hong Kong Curriculum Development Institute, personal communication September 3, 2004). Pearson and Young (2002) also acknowledge this problem for the US and that the widespread adoption of dedicated courses in technology education is most likely "an unlikely scenario" (p. 104). Perhaps this reality of limited technology education in schools is a true reflection of public perception, as opposed to the rhetoric of the technology education profession. If this is the case, a lot of work is required by the technology education profession in both the US and Hong Kong to change the status quo.

Final Thoughts

Using a similar public opinion poll to compare what Americans and Hong Kong people think about technology provided interesting contrasts and similarities. Obvious differences in cultural influences such as history, language, and political systems play a part in the formation of education policy and public perceptions. However, the universality of technology can serve as a common basis for better understanding each other. In this regard, this study attempted to add to the body of knowledge about what different cultures think about technology. Perhaps the common issues and threats identified in trying to convince a public about the need for technology education will serve as a basis for future international collaborative efforts and discussions. In this regard, it is recommended the US study initiated by Rose and Dugger (2002) and replicated in Hong Kong be expanded to other countries and cultures.

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The Ford Partnership for Advanced Studies: A New Case for Curriculum Integration in Technology Education

Richard Zinser and Paul Poledink

Introduction

The Ford Motor Company launched a new pre-engineering curriculum for high schools in the Fall of 2004. Building on an earlier manufacturing program, the development process for the Ford Partnership for Advanced Studies took approximately three years. Ford and the course designers wanted the new program to incorporate the best principles and practices of technical/technology education at the secondary level. Therefore a conscious effort was made to integrate national curriculum standards in the design phase; in addition, there are explicit connections in the instructional materials between the academic and technical content for both teachers and students. This article reviews the rationale and the strategies for academic integration, and shows how the new Ford program is a prominent example of effective curriculum development in technology education. The product of this process is a coherent series of five courses that are educationally sound and that address national standards in academics, technology, and engineering.

Background

While Henry Ford is widely acclaimed for his achievements in the automotive industry—achievements which allow many to acknowledge him as the man who put America on wheels—he was also one of the first businessmen who recognized the role that responsible corporations play in building and sustaining communities. Under his leadership, Henry Ford created a variety of schools and established supportive relationships with many educational institutions of his day (Ford Motor Company Fund, 2002). Following in this tradition of support for learning by all members of the community, the Ford Motor Company, recognizing the industry-wide need for more young people to pursue careers in engineering, math, science, and technology, created the Ford Academy of Manufacturing Sciences (FAMS) in 1990 to expose high school students to the potential of high-tech careers in manufacturing. FAMS consisted

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of four, one-semester high school courses: The World of Manufacturing, Statistical Methods for Manufacturing Quality, Workplace Technologies and Applications, and Case Studies in Manufacturing. It was designed for juniors and seniors and included a summer internship. In the mid-90s an alternative configuration was introduced with additional courses in Workplace Communications for the ninth grade, Manufacturing Organizations for the tenth grade, and Information Systems for the eleventh grade.

FAMS is a "rigorous academic, personal development, and work-based program" (Ford, 1998, p. 1) that provides students with learning in science, math, technology, and communication skills. The curriculum was positioned as a pre-engineering program; it was not intended to provide remedial instruction, because students needed Algebra and grade level reading skills to succeed. In 1994 FAMS was awarded a Certificate of Honor by President Clinton for recognition as an exemplary school-to-work program. In 1998 FAMS had been implemented successfully in 76 schools throughout the country, including Canada and South Africa, and served over 5,000 students.

Building on this legacy, Ford decided in 2000 to develop the next generation of courses to be called the Ford Partnership for Advanced Studies (PAS). The goals were to create a program that uses 21st century technology, is flexible for use in non-traditional settings such as after-school and summer venues, and to use national academic standards to assist in the design of content (Educational Development Center, 2000). Although the original curriculum included substantial academic content, this new development process provided an opportunity to make a more conscious alignment of the program objectives with national academic standards. The idea of integrating academic and technical content is not new, but the new Ford PAS program is a high profile example of the design and implementation of an integrated, interdisciplinary curriculum.

Conceptual Framework

Without a strong academic foundation, technical programs can have a narrow focus on entry-level job skills and may limit students' potential for postsecondary education; and, without an occupational context, academic education can lose its relevance and applicability to situations in which students are interested. As an answer to these two common learning limitations, the integration of academic and technical curriculum employs the "context of work, family, and community (i.e., all aspects of modern life) as the vehicle for engaging students in learning the most central, essential aspects of the academic disciplines" (Bragg, 1999, p. 186). The practice of curriculum integration therefore was used as the conceptual driver to develop the Ford PAS program so that students would be immersed in a realistic engineering environment while drawing on many other high school courses.

Definition of Integration

The topic of academic integration is often discussed in connection with other terms such as contextual learning, applied academics, applications-based instruction, inter- and cross-disciplinary studies, and career majors. Loepp (1999) defined integration as connections among a wide range of disciplines, "conscientiously applying methodology and language from more than one discipline to a theme, topic, or problem" (p. 21). Similarly, Johnson, Charner, & White (2003) described integration as "a series of conscious and informed strategies used to connect academic and vocational content so that one becomes a platform for instruction in the other over an extended period of time" (p. v). Building on the "all aspects of industry" framework, Finch and his colleagues (1997) suggested that curriculum should include instruction on a "wide range of industry or field-wide functions, concerns, issues, and technological knowledge and skills" such as community, environment, economic, finance, health, labor, leadership, management, planning, safety, and underlying principles of technology (p. 8).

Rationale for Integration

The rationale for integrating academic and technical subjects has been eloquently described by a number of authors. For example, Seemann (2003) made the case that to make informed technical decisions students should consider a wide range of criteria such as social and environmental factors. His holistic position "asserts that to understand the particular one must understand its relation to the whole" (p. 28). Further, to develop and transfer technical knowledge, it is important to understand the "why" in addition to the "how." Understanding the interdependencies between subjects helps create meaning. Importantly, educators need to teach these relationships explicitly in contrast with task and skill approaches, or short-term vocational skills. Technology is "context sensitive" (p. 36) so that in making choices and designs for technical projects the social and environmental setting needs to be considered as well.

Flowers (1998) argued that the result of typical design activities is a focus on the material product, whereas problem solving can include changes to systems or even maintaining the status quo. He contended that technology should help control the environment and meet human needs is a Western bias. Instead, students should be encouraged to consider a broad range of solutions including non-technological ones; they should weigh the short-term and long-term costs and benefits, and consider what is "best for the individual, for the culture, for future generations, and for the environment" (p. 24).

According to Edling and Loring (1996), a major objective of education should be to keep open a range of options for students, not simply skills for work or academics for college. Even though there is a well-developed body of knowledge for core academic subjects—and it seems to make sense to teach them in isolation—the reality of modern life emphasizes context, relationships, and wholes, which is best exemplified by occupations. So teaching academics in the context of a profession such as engineering provides a framework for higher, reflective learning which includes analysis, synthesis, and systems thinking; and teaching engineering using a foundation of academics and process skills helps students grasp and apply the concepts from both areas.

Benefits of Integration

Today's employers want workers to use initiative and solve problems, skills previously associated with employees who had been to college and have a good academic foundation in subjects like statistics. Plank (2001) suggested that an integrated curriculum provides students with a strong academic program and a foundation in work applications so that they can pursue a variety of levels and combinations of work and college. Such a program may also offer other motivational benefits like greater relevance of academics, working harder in academics, and more commitment to school in general.

In their discussion on using contextual learning to build cross-functional skills, Freeman, Field, and Dyrenfurth (2001) pointed out that skills such as teamwork, communication, decision making, managing resources, and information gathering are important for performance and stability in employment because employees are required to interact across functional boundaries. Thus a purely academic or technical education is not enough to prepare students for modern realities. The integrated approach often uses instructional strategies designed to build cross-functional skills such as cooperative learning which promotes positive relationships and helps students put material into their own words; contextual learning which helps students process new information by making sense of it from their individual frame of reference; and experiential learning like work-based methods and service learning projects.

The project method is typically used for integrating technical and academic subjects. Verner and Hershko (2003) reported that projects also promote the "development of systems thinking, problem solving, self-study, and teamwork skills" (p. 40). Project groups often include students with different strengths in subjects such as math, physics, and technology; and individuals are responsible for different functions of the group. The project report is a major component of the process which includes collecting and documenting activities, and making a final presentation. The authors found that students contributed significant time to self-directed extracurricular teamwork, demonstrated increased curiosity and motivation to inquire about other subjects related to the project, and took personal initiative in promoting and funding the project. Using the project method was one of the major objectives of Ford's development effort for the new program

Development of Integrated Programs

Hoachlander (1999) described some of the requirements for program development. To be effective, academic integration must accomplish a well-defined educational objective—not just be an engaging activity—and the work-related context must be of genuine interest to the students. A sustained, systematic curriculum also requires substantial time, resources, and expertise, yet "the stock of sound, tested materials is still quite limited" (p. 2). Once developed, the integrated curriculum may help the 60-70% of students who do not learn well when academic material is abstract or disconnected from practical applications. To increase the validity of courses, educators should use national and state standards for each academic subject as a basis for designing curriculum; national skill standards from the appropriate industries serve the same function for the technical content.

Bailey (1997) reported on a conference of professionals who had developed standards in either academic subjects or industry areas (i.e. electronics, metal working). Attendees used both groups of standards to design integrated projects; the standards can strengthen each other because educators may not understand the technical dimensions of the workplace and employers may not understand the academics they need. Standards are generally developed in isolation: industry standards mention academics, and academics make reference to workplace applications, but the connections are not explicit and the performance levels are not defined. Further, academic standards are established based on what students need to know to progress to the next level of education, and do not consider objectives outside of school. Meanwhile, the academic standards in industry are set very low (some may not even require a high school diploma), although they may be under-estimating what employees need to know. The area of biggest overlap is the process-oriented skills: problem solving, teamwork, inquiry, and communication. Employees use (and therefore students should learn) a variety of information sources to investigate issues and come up with answers, and they use different means and media to communicate results. So curricula should be developed from both sets of standards by performing a crosswalk to create complex examples and scenarios, and utilizing appropriate teaching strategies.

Implementation of Integration

One way or another, integration requires that teachers are given sufficient resources so they can collaborate with colleagues in different subject areas. This may necessitate individual and system changes, but the payoff is that both academic and technical courses can be strengthened. Writing about technology education, Linnell (2001) said that in order for technology to become a vital part of the curriculum in public schools, technology teachers need to collaborate with different disciplines, which will help gain acceptance for the technology curriculum.

Loepp (1999) identified several important factors in implementing an integrated curriculum. First, educators need to shift their approach to teaching from didactic instruction to constructivism to allow students to discover and apply knowledge in their problem-solving. Second, professional development is required for teachers in other content areas and in different pedagogy so teachers can move from isolation to members of learning communities. A third factor is that teachers need to be proficient in facilitating small group learning, especially experiential, hands-on, lab-based instruction.

Using authentic assessment strategies such as portfolios, performance and demonstration, and evaluation rubrics is a fourth factor in implementing integration. Ultimately, such changes will require public information strategies to help the community understand that a different education model is being used, and systemic changes in teacher preparation, certification, and assessment may be required.

The Ford PAS Curriculum

The development of the new version of Ford's existing pre-engineering curriculum was seen as an opportunity to incorporate the best practices of technical instruction for high school students. The development team used curriculum integration to establish a foundation for the program; they took into account many of the principles of integration such as including all aspects of industry, using manufacturing as the learning context, developing process skills, providing a crosswalk of curriculum standards, and insuring professional development for prospective teachers.

The process began in the spring of 2000 and the first two courses were ready for implementation in the fall of 2003. Several schools started the new program at that time by transitioning from the former FAMS program or by trying out selected modules. The complete Ford PAS program consists of five semester-long courses, each containing three six-week modules, and is designed to be taught in sequence starting in the tenth grade. The name of the new program was changed to the "Ford Partnership for Advanced Studies" to expand the meaning and scope of the program (beyond manufacturing), to emphasize the partnering with community businesses and post-secondary education institutions, and to distinguish the high school curriculum from general preparation courses.

Using a hybrid version of the backward design process (Wiggins & McTighe, 1998), the curriculum development team first identified the performance outcomes. Second, assessments were designed that address the various national standards as acceptable evidence of achieving the desired results. Third, the entire Ford business cycle and processes were used to develop learning activities that exemplified sound educational principles.

Needs Assessment

The project began by the awarding of a planning grant to the Education Development Center, Inc. (EDC) in Newton, MA. EDC first surveyed current FAMS students and teachers, a process that yielded several interesting discussion points. The responses were overwhelmingly positive, but there was also consensus that the program was somewhat outdated, especially in its presentation and use of technology. Teachers and coordinators were impressed with the philosophy of FAMS and its emphasis on communication, teamwork, and problem solving. For students, the most engaging part of the program was their participation in internships, field trips, and job shadowing. Teachers also expressed the need for a website that would provide curriculum activities and a national network of FAMS programs.

EDC also conducted a search for curricula comparable to FAMS in goals and focus. A total of 10 programs were investigated that potentially could provide ideas for development; they included "What's up in Factories?" developed by public television's WNET; "Project Lead the Way" funded by the Charitable Venture Foundation; and "IDEAS: Integrated Design Engineering Activity Series" by the American Society of Mechanical Engineers. Although each of the programs have their strengths and have experienced success with various groups of students, the Ford planning team envisioned a broader curriculum that would get students interested in engineering in a variety of business settings. While some of the existing curricula were seen as specialized in certain content areas, the new program was intended to introduce students to the larger world of business, literally from concept to consumer.

A third step in the assessment process was meeting with Ford engineers and other key staff to identify some of the major themes that should be included in the new curriculum. Ford's education and training professionals were interviewed to get their perspective on the important topics that are frequently requested by business units for training, as well as what all new employees need to know. Public presentations made by Ford engineers were reviewed to determine some of the topics that tend to surface repeatedly. Representatives from professional engineering associations were also contacted. After much discussion a list of seven overarching concepts were chosen: Systems Thinking, Lean Production, Diversity in the Workplace, Globalization, Environmental Sustainability, Six Sigma Quality, and Consumer Focus. The idea was that these themes—what Wiggins and McTighe (1998) call the "big ideas"—would be threaded through all the modules and learned by broad-based applications. A module on business decisions, for example, should highlight the necessity of balancing the need for financial profit with social and environmental concerns.

The new Ford PAS program includes three core curriculum elements. First, national academic standards are the basis of all instructional materials. Curriculum standards were procured from the following organizations:

- *Math*: National Council of Teachers of Mathematics (2000)
- *Science*: National Research Council (1996)
- *English:* National Council of Teachers of English (1996)
- *Social Studies*: National Council for the Social Studies (1994)
- *Business*: National Business Education Association (2001)
- *Economics*: National Council on Economic Education (2000)
- *Engineering*: Mid-continent Research for Education and Learning (2000)
- *Educational Technology*: International Society for Technology in Education (2000)

- *Technological Literacy*: International Technology Education Association (2000)

The instructional developers made conscious connections with these standards as they created and then reviewed the learning activities. For example, they identified areas of each activity where math could be used to quantify, describe, or display observations and conclusions; they identified areas where communication with diverse audiences, both orally and in writing, was necessary to successfully complete the activity; they identified areas where scientific approaches or principles would clearly support and explain observations and conclusions; and they identified areas where information technology was critically necessary to research, communicate, and present findings. Projects typically include a major skill area, e.g. conducting research on alternative materials for a product, which is aligned with specific standards such as physical science and conducting investigations.

The second core curriculum element is interpersonal and human performance skills which are included because they are critical for success in college, work, and life. Based on the SCANS skills (Secretary's Commission on Achieving Necessary Skills, 1991), they are divided into the areas of communication, thinking and decision-making, interpersonal, and lifelong learning. Many of these skills are also addressed in the English and Social Studies standards. The third core element to serve as the basis of the curriculum is consumer-focused business concepts which provide a realistic context for learning. This area includes the themes and technical subjects such as planning and efficiency, quality assurance, global citizenship, and consumer-driven design.

Curriculum Development

The curriculum development process began in the summer of 2001 with a contract by Ford with EDC. With the foundation of the curriculum and major themes established, the design team started contacting additional subject matter experts and searching for learning resources. Existing training materials from Ford, with the exclusion of some proprietary items, were made available to the curriculum team; they reviewed training programs on marketing, statistics, and product design for example, and considered how these materials could be adapted for the current audience and purpose. Professional associations such as the Society of Manufacturing Engineers, the Society of Automotive Engineers, and the National Council on Economic Education provided some promotional and educational materials. Other associations dedicated to specific issues like alternative energy were considered as sources of technical expertise and instructional materials. As a result of this development phase the curriculum team assimilated these ideas into a draft outline of five courses and 15 modules, along with a pool of resources for detailed information.

Next, the development of the first module began in earnest. The module format was designed and revised over a period of six months until a basic template was established, one which would serve as the basis for all subsequent modules. The format was also set for each module's Teacher's Guide which includes an overview, a brief description of each of the activities, a module planning calendar, a list of learning goals for each activity, and a list of the academic standards addressed in each activity. To illustrate the alignment with academic standards, the first activity in Module One has a learning goal which states "describe the consequences to society of the widespread use of new products". The next column shows the academic standard that is associated with this topic, in this case NCSS 8b and 8c, which refers to the National Council for the Social Studies standard on Science, Technology, and Society. This section is followed by a detailed description of the activities and provides a breakdown of each session. Suggestions for preparation, materials needed, and new vocabulary words are also included. Finally, there are specific process and content instructions provided for the teacher—in other words, lesson plans. There are additional resources for the activities such as background information on technical areas, worksheets, assessment rubrics, and quizzes, and there are suggestions for the teacher to contact local organizations for case studies and tours.

The Student Guide also includes an overview, learning goals, instructional content, and hands-on activities. Sessions typically start with thought-provoking questions, and contain interesting facts and Internet sources to find more information. Module One for example is entitled "From concept to consumer: Building a foundation in problem solving" and uses the history of the bicycle as one topic to illustrate the evolution of everyday products. Each six-week module contains projects that provide the context for the key learning points. These are performance driven activities for which students' learning is demonstrated by public presentations including appropriate media, written proposals and reports, product designs, solutions to real-world problems, analysis of research data, tests and quizzes. Another component to the modules is training on specific skill sets, such as how to conduct an informational interview at a business or how to develop a computer-generated presentation, all of which are embedded in the activities. These mini-lessons are designed to be used at the teacher's discretion for certain students that may not have all the prerequisite skills.

Each draft module was reviewed by the leadership team to ensure adherence to educational design principles; university teachers and subject matter experts from Ford were also utilized to confirm the accuracy of technical content. The modules were then reviewed by former FAMS teachers to get their initial reactions on the appropriateness for high school students. A second draft was field-tested by at least two teachers who evaluated the time allocated to the activities in the module, the effectiveness of the teaching/learning process, the reactions of the students to these processes, and the suitability of the suggested supplemental teaching materials. This process proved valuable in obtaining feedback on the pedagogical aspects of the material, especially on the instructions and timing of the activities. After appropriate revisions, copy editors reviewed the modules for the language and readability, and then a production company designed the layout and graphics.

Courses and Modules

The first two courses containing six modules were ready by the summer of 2003. A formal kickoff and training session was held by Ford and EDC for about 30 teachers and other interested parties. The training was conducted in part by some of the teachers who had tested the modules with students. They helped the prospective Ford PAS teachers with content and process ideas, the demonstration of a few of the activities, and a discussion on implementation issues. Several teachers started piloting some of the modules at their schools in the fall of 2003; many more teachers took the information back to their schools to review and plan for the following school year. A team of employees within Ford and EDC was set up to provide ongoing support and technical assistance for the teachers. A Website was also developed, for use by both teachers and students, which included, among other things, additional resources and hyperlinks to other Websites for research activities.

Table 1

Partnership for Advanced Studies Program Outline

Ford PAS Courses	Module Titles
1. Building Foundations	1. From Concept to Consumer: Building a Foundation in Problem-Solving 2. Media and Messages: Building a Foundation of Communication Skills 3. People at Work: Building a Foundation of Research Skills
2. Adapting to Change	4. Careers, Companies, and Communities 5. Closing the Environmental Loop 6. Planning for Efficiency
3. Managing and Marketing with Data	7. Planning for Business Success 8. Ensuring Quality 9. From Data to Knowledge
4. Designing for Tomorrow	10. Reverse Engineering 11. Different by Design 12. Energy in the 21st Century
5. Understanding the Global	13. The Wealth of Nations 14. Economy 15. Markets Without Borders 16. Global Citizens

The development of the other modules continued using a similar process, ensuring that courses Three and Four (Modules 7-9 and 10-12) were ready for the next school year. A complete outline of the PAS program is provided in Table 1.

State Academic Standards

One of the issues about implementing a new program is addressing the concern that some teachers and administrators have about schools meeting their state's standardized testing requirements. The specific question sometimes asked or anticipated is: How will the Ford PAS program help *my* students' performance on the state proficiency test? These tests typically measure the knowledge level of students in the core academic areas of math, science, English, and social studies. Since Michigan is the home state for Ford's World Headquarters and many assembly and manufacturing plants, the Ford PAS leadership team decided to study how the state's curriculum framework (Michigan Department of Education, 2003) is addressed by the Ford PAS program. (Certainly there is a lot of overlap between most national and state standards, but Michigan teachers are more likely to use Michigan standards as their curriculum guide).

The instructional materials were carefully reviewed, one activity at a time, to understand the learning objectives and then to identify the particular standard addressed in the activities. The product of the study was a table showing all the modules and activities, and their correlation with the Michigan curriculum standards. This document is used as a resource for teachers in the state, and as a tool to describe the Ford PAS program in meetings with prospective adopting schools. Other states are encouraged to use a similar process for their particular standards. Although this study was conducted after the curriculum was developed, rather than during the development as was the case with national standards, it was meant to show a supportive relationship between the Ford PAS program and the state guidelines for academic achievement.

Conclusions

The Ford PAS curriculum includes substantial content from the core academic areas of math, science, English, and social studies. By consciously making connections with academic subjects, this technology education program fits the definition of integrated instruction. Indeed, many of the elements of the conceptual framework for integration are embedded in the PAS courses.

The student activities are contextual and applications-based. The students learn business and engineering skills by working through projects, such as developing a tour schedule for a pop musical group, or designing a new size and shape for a soft drink bottle. Further, the activities are presented to students with a holistic view so they understand the rationale for the objective and how it relates to other subjects. The projects include all aspects of business and industry, (e.g. principles of technology, economics, marketing, and management), and are not focused solely on manufacturing production. The project method itself is a major objective: students learn how to carry out a project from the initial needs assessment to presenting the final report. In addition they learn cross-functional skills and other process-oriented skills like problem solving, teamwork, and communication.

The Ford PAS program presents schools an immediate opportunity to implement an integrated technology curriculum. Teachers can use a stock of professionally-developed and tested courses. The materials have high face validity because the development process was extremely comprehensive, including the use of national standards and subject matter experts from Ford and other professional organizations. In addition, the instructional materials can simply be downloaded from the PAS website, printed from a CD Rom, or purchased for the cost of printing. The only cost for schools is to send the teachers and other representatives to a professional development session sponsored by Ford. The modular format of the curriculum gives schools the flexibility to implement all or part of the program; one school for example is using modules 7-9 for a unit on entrepreneurship in their business program.

One question which persists regarding the design and development of Ford PAS is why a major corporation would invest their time and resources in developing a school-based curriculum. First, many firms, both large and small, recognize their civic responsibility—to give back to the community in which they do business. Often referred to as corporate citizenship or philanthropy, this curriculum development exemplifies the higher ideals often espoused by prominent corporations in the United States and around the world. There is also a strategic purpose for this initiative. The critical need for young men and women in the STEM areas—science, technology, engineering, and math—is widely recognized. Ford PAS was developed to assist in addressing these needs, not just with the recognition of the problem or need, but with a concrete tool, a program made freely available to the education community.

Such a venture is not without its areas of difficulty and concern. The Ford Motor Company was constantly made aware of the pressures upon the public school system to meet the needs of its existing constituencies. The economy places financial pressures on schools and colleges, that may struggle to maintain existing courses and programs, much less adopt new initiatives. Accountability measures dictated by federal legislation weigh heavily on public school administrators, school boards, teachers, and students. Yet, numerous studies, white papers, and research reports indicate the societal need for a highly skilled workforce to compete in the global marketplace. The Ford Partnership for Advanced Studies curriculum attempts to integrate important learning outcomes, not as a mere academic exercise, but as a partial response to the needs of young people, schools, and businesses. The implementation of the program requires a group of school professionals who understand that integrated curriculum may help students perform better in all their subjects.

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