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From the Editor

Merging, Converging, and Some Reflections on a Lava Lamp

Standard Oil Company was forced to break itself up into 34 separate entities in 1909 as a result of a lawsuit based upon the Sherman Anti-Trust Act of 1890. These entities did business rather independently from that milestone ruling until recently, when Exxon and Mobil oil companies merged. Mobil Oil was originally Standard Oil Company of New York (Socony) and Exxon was Standard Oil of New Jersey (Esso, sounds like "S. O.," for Standard Oil). Exxon, by the way, has struggled with monikers just as our field has, using Esso as well as Enco (Energy Company). Carter and Humble were also mixed in with the names due to further acquisitions (Henderson and Benjamin, 1996).

As dependency on Mideastern oil continues and oil supplies world-wide dwindle, it is quite possible that more mergers will occur. In fact, a likely scenario is that all of the oil companies will have to reinvent themselves as oil supplies become totally depleted and our transportation infrastructure uses alternative energy sources.

In similar action much later, the American Telephone and Telegraph Company (AT&T – "The Bell System") was forced to divest, creating a number of "Baby Bells." The year was 1984. These orphaned siblings started by supplying local telephone service while the mother company focused on long distance service. That, too, changed when the federal government allowed the siblings to supply long distance service as well. Not only that, but the new laws allowed telephone companies to supply television signals and the cable companies to supply telephone service. Then, suddenly, wireless telephone technology reached the hands of the consumers, with service at the beginning provided almost totally independent of the original Bell System. A few Baby Bells like Verizon jumped into the wireless market early and became leaders, while the mother company, AT&T, got into the wireless market and then rather abruptly bailed out when it sold the wireless end of its business to Cingular only a few months ago.

Beyond all this, who would have thought that IBM would get completely out of the personal computer manufacturing business as they did a few months ago? Who would have thought that Apple would become an online supplier of music, first for its iPod personal music player, and then for the rest of the world? And who would have thought that Apple would switch to a microprocessor from Intel, of the same family as most of the rest of the personal computer world? Who would have thought that Black and Decker Corporation, the power tool namesake, would have gotten into the small appliance business by purchasing that product line from General Electric? Who would have thought that the tobacco giant, R. J. Reynolds, would get into the food business? Who would have thought that Chrysler and Daimler would merge?

The number of mergers in the business world has increased dramatically over the past several years. The rationale for these mergers is based upon business principles and includes such factors as reducing competition by joining together, economy of scale, building strength and power, and survival. Often mergers grow out of questions of "What business are we really in?" and "What business do we want/need to be in?" Questions like these are important ones for us to ask ourselves as well.

Aside from business mergers, but nonetheless often an influence, are convergences of technology. Associate Editor Mark Sanders often reminded me of the prediction that Nicholas Negroponte, Director of MIT's think tank Media Lab, made about the convergence of three technologies, represented by three industry sectors: the Broadcast and Motion Picture Industry, the Print and Publishing Industry, and the Computer Industry (see Brand, 1987, p. 10). His prediction has proven itself to have some validity, though the convergence is behind his prediction and is still occurring.

Technological convergence is also occurring between personal digital assistants (PDA's) and cellular telephones. Cell phones initially were just telephones. Then they began to adapt features of the PDA's, such as phone books, which became contact databases. Then came digital cameras built into the cell phones with the capability to send images to another cell phone or to the whole world via the Internet. Likewise, PDA's began to have cell phone capability, with the PalmOne Treo series being one example. Call these devices what you wish, but the technologies have converged into one.

The capabilities of faxing, printing, copying, and scanning have converged into a single machine that has been available for some time now. It surely makes sense, too, since the technology of all these functions rely together on digitizing an image. I am surprised that these all-in-one machines have not caught on more than the have, but I suspect that literate consumers realize how quickly the technology changes and when significant advances are made in one of the capabilities, it would require the replacement of the entire machine to realize the advantage. I am also surprised how my colleagues and I continue to print documents on the printers in our offices and then walk down to the centralized copier in the main office to make multiple copies. Networked copiers have been available for some time now and the cost will no doubt decrease as competition to include networking increases.

When I first started teaching, I was concerned about the diversity of courses that were offered in our field. It seemed to be a boundless mix of everything from automotive repair and woodworking to crafts and leatherwork. I felt elated when the field finally converged on the organizers of communication, construction, manufacturing, and transportation. Some theorists reduced these organizers to three by converging construction and manufacturing into "production." Though this made theoretical sense, it was difficult to put it into teachable practice. A few textbooks tried to homogenize the two areas, but eventually it seemed that the first part of the book was manufacturing and the last part was construction, or vice-versa. It was a failed merger.

Similarly, there have been challenges in teaching transportation without making the fundamentals of power and energy a predominant part of the instruction. In thinking about this, I have always wondered why nearly every curriculum structure that we have developed has had only one level of organization (e.g., communication, construction, manufacturing, and transportation) when it seems that there should be at least two or three levels. Unlike the convergence that has occurred in some other school subjects, our curriculum has been diverged with the Standards (ITEA, 2000). It will be interesting to see if the medicine and agricultural areas from these Standards are converged in the future, either together with each other or into "production."

Over the years, I have observed the connections made with other constituencies and organizations. In the 1970s I learned about some efforts to connect with Junior Achievement (www.ja.org; also see May, 1954). It seemed like such a natural fit to our field, with their emphasis on entrepreneurship and our emphasis on the technical and managerial aspects of manufacturing. I recall the close relationships that we had with the Associated General Contractors and the Society of Manufacturing Engineers, and the assistance they gave to our curriculum development efforts in the 1970s, especially the *World of Construction* (Lux, D. G. and Ray, W. E., 1970) and *World of Manufacturing* (Lux, D. G. and Ray, W. E., 1971), respectively. I think about the Science, Technology, and Society (STS) movement that started in the late 1960s and how important our involvement in that effort seemed to many at the time (see, as a resource, http://www.chass.ncsu.edu/ids/sts/). In fact, Melvin Kranzberg (now deceased), a premier historian of technology, spoke at a conference of the American Industrial Arts Association (now the International Technology Education Association) and the Association published a significant work that he authored (Kranzberg, 1964).

The decade of the 1990s might be termed the Technology, Science, and Mathematics era where a number of efforts, often funded by the National Science Foundation (NSF), were underway. The emphasis was on integrating these three subject areas in a way that made sense to students and would motivate them to learn. I vividly remember when the principal of the junior high school in which I was teaching said that the only way to get "ordinary kids" (i.e., the vast majority) interested in science is through industrial arts (now technology education). The year was 1966, my first year of teaching. That belief led to a major project, with my colleague Mark Sanders, to integrate technology, science, and mathematics, nearly 30 years later (LaPorte & Sanders, 1995). Today, nearly 40 years later, I still believe in that notion but I still do not know how to do it in a highly effective manner.

The present decade, just past the half way point, seems to be characterized by alliances with engineering and educational technology, two disparate counterparts, indeed. A number of engineering projects have been funded by NSF and are currently in development. Two articles by Theodore Lewis, Professor at the University of Minnesota, have addressed engineering between the covers of the JTE; one appeared in the last issue and one is in this issue. Also in this issue is an article by Yaron Doppelt from Israel that has clear connections to engineering.

No one knows where our budding relationship with engineering will take us. In reflecting, though, about what I have read regarding this notion over the past couple of years, there is some confusion in my mind for it seems that some would have us in the business of preparing engineers at the secondary level rather than developing the technological literacy of the masses, albeit a vocational purpose instead of a general education purpose.

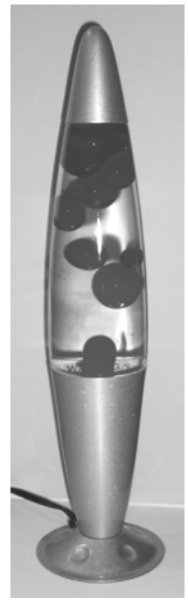
Clearly we draw from the same discipline base as engineering. Clearly engineering is starting to value hands-on problem solving like we have practiced from the beginning of our history. Clearly engineering has realized the importance of their presence in K-12 education. Clearly, engineering is the application of mathematical and scientific theory to the solution of practical problems. Rushing forward from the back of my mind, though, are the images of a relatively large number of students with whom I have worked over the years, at three land-grant universities, who transferred into technology education from engineering. They transferred precisely because they developed a grave disdain for the application of mathematical and scientific theory, at least the way in which it was taught to them in engineering courses. Engineering, though, is beginning to change the way in which they teach their future engineers and it is beginning to converge with the way in which we teach our future teachers of technology. The new master's degree/teaching licensure programs at institutions like Colorado State and Virginia Tech, that rely on students with undergraduate degrees in engineering, will provide us with an interesting test bed for research.

Stephen Petrina at the University of British Columbia has been promoting the merger of technology education and educational technology for several years. His initial arguments were presented in the JTE (Petrina, 2003) and he continues to develop them on the listserv for the Council for Technology Teacher Education. The commonality of purpose between these two areas has increased in recent years, with educational technology becoming more content based and literacy focused, and technology education becoming more reliant upon educational technology to deliver content, especially modular-type programs, and to engage students in the design process. Many technology teachers find themselves teaching computer use and even serving as educational technology experts in the school. Clearly there is a convergence in process.

In scanning newspapers and journals on mergers, a lot of factors are posited for their success. The one that seems most recurrent is the compatibility of cultures between the two entities being merged. In reviewing in my mind the linkages that might have taken place and did not, I can explain them away with cultural differences, with varying strengths of argument. Perhaps, though, these potential mergers and convergences that failed to happen are just as they should be in our dynamic society, consistent with Toffler's (1970) notions of adhocracies—connections that come and go as political and sociological needs and interests change.

I have been driven by logic throughout my professional life. That is, if an idea did not make logical sense to me, then I could not support it and did not understand the intentions of those who did. They were the opportunists. They chased the money and the political power bases, regardless of what direction they might lead or how inconsistent they might be with the direction in which our field had decided to go. I abhorred them for not being orthodox. Now, in the autumn of my career, I realize that the opportunists are essential to our field, for they open new doors and new eyes to our work and its importance to society. There are tradeoffs to the relationships that the opportunists make, but there are equivalent tradeoffs to the actions of the orthodoxists, like myself.

I am mesmerized by "lava lamps." I watch the globules of "lava" split apart and then rejoin other globules in an endless cycle of merging and converging. No patterns are ever the same and the paths of motion are perpetually changing. It seems so much more complex to me now, though, than it did in the past.



A "Lava Lamp"

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Articles

Assessment of Project-Based Learning in a MECHATRONICS Context

Yaron Doppelt

Introduction

Project-based learning (PBL) that has authenticity in the pupils' world enables the teaching of science and technology to pupils from a variety of backgrounds. PBL has the potential to enable pupils to research, plan, design, and reflect on the creation of technological projects (Doppelt, 2000). Imparting creative thinking within the design process of pupils' projects not only requires changing the teaching methods and learning environment, but also adopting new assessment methods such as student portfolios. Engineering education, which is common in Israel, has a unique structure in that it combines practical and theoretical knowledge, synthesizes vertical and lateral thinking, and creates a rich and flexible learning environment.

The CTT (Creative Thinking in Technology) program (Barak & Doppelt, 1999) integrates Co.R.T. Thinking tools (De Bono, 1986) into the technology curriculum using the LEGO-Logo learning environment for creating authentic projects. The program began in 1994. Pupils study lateral thinking tools in order to deal with different alternatives, to consider multiple factors, and to refrain from premature judgments on ideas. They use vertical thinking tools in order to document their design process and to calculate and to structure programming for the control of their projects. Earlier field research by Barak, Waks, & Doppelt (2000) showed that pupils prefer a learning environment that emphasizes planning and building activities and team projects. Pupils have stated that these aspects of a learning environment contribute to creating challenges, curiosity, imagination, and success in studying technological subjects (Doppelt & Barak, 2002). As the CTT program evolved, a Creative Thinking Scale (CTS) was

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developed in order to assess pupils' portfolios (Barak & Doppelt, 2000). The study reported herein extends research conducted on the CTT program and proposes a Creative Design Process (CDP) that can be assessed using the CTS.

Theoretical Background

The theoretical background of this study cuts across three areas of inquiry: engineering education, the infusion of creative thinking into the design process, and the assessment of project-based learning.

Engineering Education: A MECHATRONICS Context

De Vries (1996) claimed that we should help pupils integrate knowledge from science and other disciplines into the design processes. It is evident that there is a role for science education and that science education remains a crucial part of general education, even where technology education has gone beyond the "technology is applied science" paradigm. Technology education is an equally valuable subject to science education, and both subjects should be taught (Gardner, 1997).

Engineering education in Israel is part of the comprehensive high school curriculum. At the end of junior high school, pupils have to choose one or more areas as a "major," such as the Sciences, Humanities or Technology. Within Technology is Engineering. The Engineering curriculum for high school in Israel contains several core subjects that are related to physics and mathematics, such as civil engineering, computers and electronics, and mechanics and control systems. MECHATRONICS is a new sub-major in the mechanics and control area. Pupils study MECHATRONICS for three years, 10th – 12th grades. They study physics, system control, mechanics, and programming for five hours per week, with a total time devoted to all classes of 20 hours per week. This syllabus is about half of their weekly schedule.

The MECHATRONICS syllabus has been implemented in nine schools since 2000/2001. In 2003 there were fifteen schools that chose to advise their pupils to take this syllabus. The MECHATRONICS curriculum suggests that educators create rich learning environments filled with real world applications. The assessment processes of learning outcomes in a rich learning environment have had an important impact on the learning process (Doppelt & Barak, 2002). In addition, the perspective of pupils on the most influential characteristics of the learning environment is important for the teaching-learning process and for designing the learning environment (Doppelt, 2004). This study suggests a way of infusing creative thinking into the design process during project-based learning (PBL).

Infusing Creative Thinking into the Design Process

The design process is similar to the process of problem solving. Many general structures for design processes appear in the literature. A generalized approach to structuring the design process might include six stages: defining the problem and identifying the need, collecting information, introducing alternative solutions, choosing the optimal solution, designing and constructing a prototype, and evaluating and correcting the process. The design process might also include four thinking levels:

1. Understanding existing systems
2. Systematic and functional understanding of engineering systems
3. Applying set procedures for analysis and synthesis
4. A controlled design process that assures that the above steps are applied by the students.

(Mioduser, 1998)

Teaching technology using a generalized design process has been criticized by researchers who have claimed that it is difficult for pupils, and even for teachers, to learn how to use it (McCormick & Murphy, 1994). This is not surprising given that different technology disciplines go about designing in different ways (Hill & Anning, 2001). In order to avoid the pitfalls of a generalized design process, teachers should assist pupils to integrate the knowledge of the various disciplines and learn the applicable standards and rules, as well as the underlying scientific principles and economic concepts (De Vries, 1996). This article will describe a design process that applies these suggestions and is sensitive to the authenticity of the pupils' projects. This design process was based initially on the PISCO framework (De Bono, 1986). PISCO stands for: Purpose, Input, Solutions, Choice and Operations. Infusing the teaching of thinking skills into a specific disciplinary course may provide a rich learning environment that will contribute not only to the development of thinking skills but also to a better understanding of the discipline under study (Glaser, 1993; Ennis, 1989; Zohar & Tamir, 1993).

De Bono (1986) differentiates between two types of thinking: *lateral thinking*, which refers to discovering new directions of thinking in the quest for a wealth of ideas, and *vertical thinking*, which deals with the development of ideas and checking them against objective criteria. Lateral thinking and vertical thinking are quite different processes. It is not a matter of one process being more effective than the other, as both are necessary. Rather, in order to be able to use both effectively, one must appreciate their differences. Lateral thinking is a central, but not singular, component of creative thinking. Waks (1997) pointed out that during work on a technological project, lateral thinking initiates the learning process while pupils seek alternatives and examine different solutions. Vertical thinking is essential at the stage of choosing a solution and developing it. Vertical thinking and lateral thinking complement each other, and both are the essential elements of creative thinking (De Bono, 1986).

Assessing Creative Thinking in PBL

Technological systems that are controlled by a computer provide a rich learning environment and expose the learner to a variety of representations and configurations, such as realistic models, simulations, mathematical models, algorithms, graphics, and animations. One of the better-known examples of such a rich computer-based learning environment is the LEGO-Logo system (Doppelt & Armon, 1999; Jarvinen, 1998). Resnick and Ocko (1991) stated that this learning environment puts children in control because they formulate their own designs and experiments and work on projects that they care about personally instead of reproducing someone else's experiment.

Project based learning in technology encourages pupils to work in teams (Barak & Maymon, 1998; Denton, 1994). In this way, pupils combine "hands-on" activities with what Papert (1980) has termed "heads-in" activities. Project-based learning (PBL) could be used as a tool to develop pupils' competencies by working on integrated projects (Barlex, 2002). Project-based learning through authentic issues taken from the pupils' world enables pupils from various backgrounds to study science and technology in a way that makes sense to them (Seiler, Tobin & Sokolic, 2001). An authentic project deals with real life situations and, by definition, is integrative in nature. This approach has been implemented throughout the world and past researchers have shown interesting findings regarding the opportunities afforded by PBL (Barak & Doppelt, 1999, 2000; Barak, Eisenberg & Harel, 1995; Barlex, 1994; Doppelt, 2003; Doppelt & Barak, 2002; Hill, 1998; Resnick & Ocko, 1991). One of the key elements for success in PBL is engaging the pupils in the assessment process.

Imparting creative thinking within science and technology education not only requires changing the teaching methods and learning environment, but also adopting new assessment methods, such as portfolio assessment, which is based on records of pupils' activities. The portfolio might consist of such items as written material, computer files, audio and video media, sketches, drawings, models, and pictures. The portfolio reflects what pupils have learned, how they question, analyze, synthesize, solve problems, and create new ideas, and how then design and build useful products or systems. The portfolio also shows how pupils interact intellectually, emotionally, and socially with others (Collins, 1991; Wolf, 1989).

Barak and Doppelt (1999) have shown that pupils were able to cope with complex problems and they developed solutions that depended on creativity, supporting the notion that they applied lateral and vertical thinking. Pupils created portfolios containing documentation of their creative thinking and the learning processes in which they were engaged. Over a period of several years, each class developed criteria for assessing their portfolios. On the basis of these experiences, a Creative Thinking Scale (CTS) was developed and was formally applied to the assessment of pupils' portfolios (Barak and Doppelt, 2000).

The suggested assessment scale of creative thinking can help educators strive for a gradual development of higher-order thinking skills in two main areas. The first is the choice of a project topic that that pupils make. This includes dimensions of complexity, originality, and creativity on the one hand and the extent of mathematical, logical, and scientific thinking on the other. The second area considers the thinking and learning processes applied as the pupils developed their project and includes problem solving, teamwork, and reflective thinking. Thus, learning through the designing and implementation of technology projects based on portfolio assessment and directed towards a systematic development of vertical and lateral thinking may promote teaching and learning that assist the successful integration of the pupil into the dynamic and changing world outside of the school once they graduate.

Background and Precursors

Intervention Program

The intervention program included in-service training of teachers for a duration of 112 hours. This consisted of twenty-eight workshops of four hours per meeting during the school year. The program was aimed at introducing three main topics: the tutoring process, the Creative Design Process (CDP), and assessment using the Creative Thinking Scale (CTS) criteria. Eighteen teachers from nine schools who had taught MECHATRONICS since 2000 were involved in the project.

Six Stages of the Creative Design Process (CDP)

The creative thinking framework was originally developed by De Bono (1986). He based this framework on five thinking steps that he named "PISCO" - Purpose, Input, Solutions, Choice and Operations. The Creative Design Process (CDP), which is presented in this article, adopts this creative thinking framework and extends it to project-based learning (PBL) in technology education.

The creative thinking tools that are suggested in the CDP are part of the Co.R.T thinking program (De Bono, 1986). They include P.M.I (Plus, Minus, Interesting), C.F.A (Consider All Factor), Rules, C&S (Consequence and Sequel), O.P.V (Other People's View) and F.I.P (First Important Priorities).

First stage: Design Purpose. The first step in the design process is defining the design problem. The pupils need to set the design goals. These goals must fit the definitions of the problem. The achievement of these goals will be under the restrictions that the designer has set forth and include budget, availability, equipment and tools, schedule, and so on. Three steps are recommended to the pupils for the documentation of this first stage:

1. *The problem and the need* – Pupils describe the reasons that motivated them to choose their project. They also define the problem and define the needs that their solution will address.
2. *The target clientele and restrictions* – Pupils describe the target clientele and define the restrictions that they must take into consideration. The Rules thinking tool can help you consider rules, standards, and other restrictions.
3. *The design goals* – The pupils define the necessary demands they expect to be met by the system.

Second stage: Field of Inquiry. The second step in the design process is to define the field of inquiry in which their problem resides. This is founded on the problem definitions and goals from the first step. Pupils must research and analyze existing systems that are similar to the one they are developing. Pupils need to organize the documentation of their inquiry. This includes the following main areas:

1. *Information Sources* - Books, professional magazines, manufacturers' catalogs, and Internet sites.
2. *Identification of Engineering, Scientific, and Societal Aspects* - Engineering concepts, scientific concepts, societal and environmental aspects, cultural values, and potential issues and dilemmas.
3. *Organization of the Information and its Assessment* – Arrangement of the information according to the goals and restrictions of the problem. Pupils need to summarize the information gathered so that the design problem and approach are informed by it. Pupils should express their opinions regarding the match of the information they have gathered to their design problem. They must also provide a rationale for why their evolving design is a better alternative to systems that already exist.

Third stage: Solution Alternatives. The third step in the Creative Design Process involves the consideration of alternative solutions to the design problem. This is a lateral thinking stage and includes three components: Ideas, Factors, and Opinions (of other people). Pupils need to be educated so that they feel freedom in their thinking and are not discouraged by the judgments that other pupils and their friends might make. This strategy will increase the likelihood that numerous design possibilities will be considered, with the intent of inspiring creativity and arriving at an idea that no one else has developed. There are no bad ideas at this stage. The pupils are presented the following suggestions and guidelines:

1. *Ideas Documentation* – The use of the **P**.**M**.**I** (**P**lus, **M**inus, **I**nteresting) thinking tool is recommended to the pupils so that they consider as many ideas as possible and formally evaluate them, considering all aspects. The aspects of the ideas are rated as positive, negative, or interesting, meaning that they have promise but more investigation is needed.
2. ***C**onsider **A**ll **F**actors (**C.A.F**)* – Pupils are asked to write down all the factors related to the system they are designing. They must consider the perspectives of the consumer, the designer, the manufacturer and the marketer.
3. ***C**onsequence and **S**equel (**C&S**)* – Pupils must consider and document all of the consequences of each of their ideas on such elements as the environment, society, and the individual. Both short term and long term consequences must be considered.
4. ***O**ther **P**eople's **V**iew (**O.P.V**):* - Pupils must seek the opinions of others about their ideas and they must document what they find.

Fourth stage: Choosing the Preferred Solution. **-** The fourth step in the design process is choosing the preferred solution. The choice is made from the various ideas that were documented in the third stage. The solution chosen will possibly fulfill the following criteria:

1. Have the largest amount of plus and/or interesting points and the least minus points
2. Considers as many factors and viewpoints as possible.
3. Is adequate in both the short and long term.
4. Appears to be a good solution in the minds of others.
5. Meets all the requirements set forth in the definition of the problem.

Table 1 is designed to assist pupils in choosing the best solution.

Table 1
An evaluation scheme for evaluation pupil ideas

	Very Weak (1)	Weak (2)	Average (3)	Good (4)	Very Good (5)
Positive Points					
Interesting Points					
Factors Involved					
Viewpoints					
Short/Long Term					
Other People View					
Necessary Demands					
Desirable Demands					

The use of the **F.I.P (F**irst **I**mportant **P**riority) thinking tool is recommended to pupils in order to help them set priorities. This thinking tool could assist in choosing the optimal solution.

Fifth stage: Operation Steps. The fifth step in the design process is planning the operational ways to implement the chosen solution. Planning must be consider the following points:

- Sometimes the chosen solution is a complex system. Dividing it into sub-systems may assist in defining the steps that are needed to develop the solution.
- In many cases choosing the ideal materials, parts, and mechanisms are a central part of the design process.
- The sketches and drawings (computer-generated as well as traditional) are important to the presentation of a design.
- Choosing machines, tools, and manufacturing processes are necessary steps to creating a prototype.
- Planning how to make the prototype is critical to success. Planning activities include developing a timeline of tasks and making sure the necessary materials, parts, machines, human resources, and so forth are available and will be available when needed.

Six stage: Evaluation. The last step is to evaluate the overall process and product. This is a summative evaluation and relates back to the formative evaluation steps that were done as the idea was developing. In this final stage the pupils need to document:

- What difficulties were encountered and what methods were used to overcome them?
- Does the system actually provide a viable solution to the problem?
- Does the prototype fulfill all its performance requirements?
- In what way could the prototype be improved?
- What are the implications for further development?

The Creative Thinking Scale

In this study the Creative Thinking Scale (CTS) was used to assess the suggested Creative Design Process (CDP). The CTS was introduced to the teachers during the workshops mentioned earlier. It consists of the four thinking levels that De Bono (1996) defined:

1. Awareness of Thinking
   The first level deals with developing an awareness that thinking is a skill that can be developed. Pupils are taught how to prepare to engage in thinking about something, how to conduct inquiry, and how to listen to and evaluate the opinions of others.
2. *Observation of Thinking*
   The second level deals with observing the consequences of action and choice, considering other people's views, and comparing alternatives.
3. *Thinking Strategy*
   The third level deals with the directed use of some thinking tools, organizing thinking as a sequence of steps, and using thinking to define goals.
4. *Reflection upon Thinking*
   The fourth level deals with a systematic use of thinking tools, clear awareness of the need for reflective thinking, self-evaluation of thinking, designing thinking tasks, and methods to implement these tasks.

The CTS evaluates the pupils' portfolios across two dimensions. The first considers the design, construction, and evaluation of the product or system. Evidence of lateral thinking, including originality, authenticity, usefulness, and unique design is sought. Likewise, evidence of vertical thinking is also sought and includes functionality, reliability, accuracy, geometric structure, and the application of scientific principles.

The second dimension considers the processes of learning and includes thinking, problem solving, and teamwork. Evidence is sought of individual and group efforts in problem solving, collaborative decision-making, and leadership. Table 2 presents the CTS, the development of which was detailed elsewhere (Barak & Doppelt, 2000).

Table 2
The Creative Thinking Scale (CTS)

	Portfolio's Components	
Achievement Levels	**Design, construction, and evaluation of the system or product**	**Learning, thinking, and problem-solving activities**
Level 1: Awareness The awareness to consider thinking as a skill which can be developed; prepare to think about something; prepare to inquire; prepare to listen to other people opinions.	Standard diagram of a system or product taken from available literature. Basic explanation of the model and its construction. Description of the model by means of pictures or sketches.	An example of solving a simple problem in planning and construction. Division of tasks among the team members. A few examples of using lateral and vertical thinking tools.
Level 2: Observation The observation of consequences of action and choice; consider the views of others; compare alternatives.	Original schematic diagram of system or product designed by the pupil. Detailed drawings of the model. Specification of planning and construction stages including calculations, specifications or computer programs.	Justified examples of choices among a number of alternatives. Information exchange and reciprocal help in the team. Various examples of using thinking tools.
Level 3: Strategy The directed use of some thinking tools; organizing the thinking as a sequence of steps; using thinking to define goals.	Original system functional block diagrams, structural tree or flow chart. Description of a number of iterations in the planning and construction of the model. Comparison among possible models and choosing from them.	Examples of the contribution of individuals and teamwork to solving complex problems. Evidence of the planned use of the thinking tools, open-mindedness, and postponing decision making (lateral thinking); setting priorities, goals and criteria (vertical thinking).
Level 4: Reflection A systematic use of thinking tools; clear awareness of reflective thinking; self-evaluation of thinking; designing thinking tasks and methods to implement these tasks.	Examination of the final product's features, compared to the set goals. Conclusions on successes or difficulties during the development process. Suggestions for improvement in the planning and construction process.	Conclusions drawn from the influence of the team's collaboration on the completion of the project. Pupils' view on the influence of the team's functioning on thinking and learning processes. Assessment of the selected solution compared to the goals.

Method

This study aimed first to investigate the way pupils design their projects. The second aim was to describe the assessment of Project-Based Learning (PBL). The third aim was to explore the ways teachers set goals for their pupils according to the CDP and the CTS. A qualitative approach was used in order to foster collaboration with teachers and to gain close interaction with pupils, teachers, principals, and supervisors from the Israeli Ministry of Education.

In 2003 there were nine schools that offered MECHATRONICS as a major during the 10^{th}-12^{th} grades (16-18 years old). Eighteen teachers were involved in delivering the MECHATRONICS courses. Approximately 180 pupils have graduated from high schools with MECHATRONICS as their major. Pupils' projects are examined through a matriculation examination at the end of the 12th grade. In these examinations a supervisor arrives at each school and the pupils are required to present a portfolio of their design process and the final product or system that resulted. Team projects are assessed the same as single projects. The examination supervisor asks questions of each of the pupils in the team.

A national contest was organized for all the Israeli pupils in the MECHATRONICS programs. All the pupils knew at the outset of the contest that they would be required to design, construct, and to program a system that would assist humans. Criteria for assessing the projects were developed with the teachers. The teachers were instructed to introduce the criteria to their pupils six months prior to the contest. The assessment process during the contest itself focused on evaluating the design process and resultant products based upon a presentation made by the pupils.

Agreement was reached among the teachers on the criteria for assessing the pupils' work during a meeting six months before the contest. These criteria were validated in advance of this meeting through the agreement of five senior teachers from schools that were not participating in the contest and five researchers from the Technion – Israel Institute of Technology. These ten individuals were invited at the contest to serve voluntarily as members of the assessment committee.

Participants

In all nine schools the teachers assessed the projects using the developed criteria. Each school could send three teams to the contest. Fifty-four pupils were chosen by their teachers to participate in an Israeli national MECHATRONICS contest, which was held at the Technion. The pupils were in the second semester of their 12th grade and they had been learning MECHATRONICS according to the syllabus that was described earlier. The teachers of these pupils, eighteen from the nine participating schools, applied PBL in their classes during the 12th grade.

Data Collection and Analysis

As mentioned earlier, the CDP and the CTS had been introduced to the teachers during a workshop. The author actively participated in the workshop. During the workshop, criteria for assessing PBL were agreed upon among the teachers. These criteria were used to assess the pupils' projects in the national contest. Six month prior to the contest, the teachers and pupils became familiar with the assessment criteria. The pupils were required to present their projects during the contest. By way of these presentations, the researcher was able to investigate the implementation of the CDP and the impact of the CTS upon pupils' projects.

Findings

The findings are presented in three categories. First, projects are briefly described, showing the variety and authenticity of the pupils' work. Second, a representative example of the assessment process is presented. Finally, the judges' assessment of the MECHATRONICS projects in the national competition is presented.

The Projects

Fifty-four pupils were eligible to enter the national MECHATRONICS contest, representing 18 projects. Of these, three teams were unable to bring their projects to the final level needed to actually compete in the contest. In the end, forty five pupils representing 16 projects were in the competition. Only one project was done by a student working alone.

The Judging Process

The pupils presented their projects to an assessment committee consisting of teachers from the participating school, senior teachers from schools that were not participating in the contest, and researchers from the Technion - Israel Institute of Technology. Procedures were used to assure that a given project was not judged by a teacher of the pupils who produced it.

There were two stages to the assessment process. In the first stage, the projects were presented to teams of three judges. Approximately three projects were evaluated by each team of judges. From this procedure, six projects moved on to the second, or final, stage of the evaluation process. The descriptions in Table 3 show that the projects were authentic and varied.

Table 4 presents a representative project, which demonstrates the assessment process. This example is project No. 7 from the final assessment presented in Table 3. These findings show a high-level of agreement among the independent assessments of each criterion as scored by the judges. The scale for the scoring was 10 percent for the first and the last criteria, and 20 percentages for each of the other criteria.

Table 3
MECHATRONICS Projects

Project No.	Project Description	Pupils on Team
1	Automated control system for a hoisting machine	4
2	Automated, multi-player basketball game	3
3	Simulator for jogging	2
4	Automated system for changing and playing compact discs	1
5	Computerized Scanner	2
6	System for coaching Ping-Pong players	6
7	Simulation of riding a bicycle	2
8	Automated system for finding and collecting tennis balls	2
9	Computerized system for playing chess.	3
10	Computer controlled model of a detention facility	2
11	Computer controlled system for coaching boxers	5
12	Automated system for replacing wheels	3
13	System to assist pupils in learning about computer control	2
14	System for coaching tennis players	3
15	Automated system for identifying and neutralizing bombs	3
16	Computer controlled system for pumping water	2
Total		45

Table 4
Independent judgment according to agreed criteria

Criteria	Judge No. 1	Judge No. 2	Judge No. 3	Mean
Presenting the needs and the system's goal	9	8	10	9.0
Presenting alternative and creative solutions	19	15	18	17.3
Analyzing the chosen system	18	15	18	17.0
Performance of a working controlled prototype	12	13	12	12.3
Sophistication of the control program	20	17	18	18.3
Presentation of design stages	8	7	8	7.7
Total	86	75	84	81.7

Judge 1 was a senior teacher who had not participated in the intervention but was familiar with the criteria. The correlation between judges 1 & 2 was 0.957; between judges 1 & 3 it was 0.990 and between judges 2 & 3 it was 0.944. Similarly, high correlations were found among all of the other assessments, which were scored by the other judging teams. The assessments at the same time and there was no interaction between one team and the other teams. This shows that the judges have a shared perception of the criteria.

The Final Assessment of the Projects

Table 5 presents the findings from the final assessment process. In the final stage the pupils presented the six projects, shown in bold in the table, to the committee in a large auditorium. In the auditorium 160 guests watched the final contest and included families, teachers, school principals, supervisors from the Ministry of Education, and researchers from the Technion. The assessment committee watched each presentation and assessed the six projects according to

Table 5
Final scoring of each participating project

Rank order of projects	Presents the purpose of the system	Presents alternative and ct	Analysis of the chosen system	A working, controlled prototype	Complexity of the control program	Presents the design stages	Sum (100 possible)
1	10.0	17.7	20.0	20.0	19.7	8.7	**96.0**
2	10.0	17.7	19.7	16.7	20.0	10.0	**94.0**
3	10.0	16.7	18.3	20.0	18.3	10.0	**93.3**
4	10.0	18.0	17.7	17.3	20.0	9.3	**92.3**
5	8.7	14.7	17.7	20.0	19.3	9.0	**89.3**
6	9.0	18.3	16.3	16.3	18.7	8.7	**87.3**
7	9.0	17.3	17.0	12.3	18.3	7.7	81.7
8	9.7	15.3	17.7	14.7	14.0	9.0	80.3
9	7.7	15.3	15.0	18.3	15.3	8.3	80.0
10	8.0	13.3	14.3	16.0	20.0	8.0	79.7
11	8.0	13.3	15.0	20.0	15.0	8.0	79.3
12	6.3	13.3	12.3	20.0	17.7	8.0	77.7
13	7.0	11.3	16.7	17.7	19.0	5.3	77.0
14	8.3	15.0	14.3	13.3	16.7	8.3	76.0
15	10.0	13.3	12.3	16.0	11.7	10.0	73.3
16	6.7	13.3	12.3	15.0	15.0	7.0	69.3

the developed criteria, as mentioned previously. The six projects were an automated controlled system for lifting a hoister weight, an automated multiplayer basketball game, a mini football game, a jogging simulator, an automated system for changing and playing compact discs, a computerized scanner, and a system for coaching ping-pong players.

Discussion

Seven years of experience in implementing the CTS in order to assess pupils' projects demonstrates how this methodological assessment can help educators develop and evaluate learning assignments aimed at fostering creative thinking in technology (Doppelt & Barak, 2002). Through the CDP and systematic reflection on it, pupils can develop awareness of their internal thinking processes and document them. The purpose is not to educate pupils to design according to some generalized procedure, external to them, for constructing their ideas, solutions, and products (De Vries, 1996). This is counter to creativity. Rather, it is an educational goal to teach them to document their thinking properly and thereby enable them to reflect on their creations and how they developed them. Research was recently conducted in this area by Doppelt, Mehalik, and Schunn (2005).

Pupils are expected to internalize their adaptation of the design process, to use it in their own way, to apply it to new situations, and to demonstrate general patterns of lateral and vertical thinking in their technology projects. No less important is fostering pupils' meta-cognition, or 'thinking of thinking'. The way pupils commence, progress, and complete their project demonstrates that creative thinking in technology is a combination of vertical and lateral thinking (Waks, 1997; Barak & Doppelt, 2000).

In addition, the projects reported herein show that pupils in high school can create, design, implement, control, and document authentic, real-life projects instead of solving well-defined problems prescribed by the teacher. In fact, the criticism of current engineering education is that there is an overemphasis on solving well-defined, closed-ended problems (NSPE, 1992). Furthermore, pupils have proven through their projects that they are capable of dealing with the "large definition of DESIGN" – that the DESIGN activity does, in fact, encompass the entire process of planning, designing, constructing, and managing the development of a product (De Vries, 1993; Hill, 1998).

The CTS has enabled teachers and researchers to set goals for the pupils (and for the teachers) during the PBL. The consistency of the judges' scores and the successful application of the criteria developed by the teachers strengthened their validity. The findings of the assessment process indicate that the CDP and the CTS are useful and can be implemented by teachers who have participated in a suitable in-service training. The assessment of technology education can serve as a highly integrative element in technology education that allows pupils to combine and integrate various knowledge and skills (De Vries, 1997).

Conclusions

The in-service teacher workshop assisted the teachers in discussing tutoring issues, design stages, and assessment criteria. The independent judging showed a high-level of agreement among the judges. These assessments were similar to the researchers' and senior teachers' assessment in the final stage of the contest. The researchers and senior teachers had not taken an active part in the tutoring process during the school year. They were familiar, however, with the criteria and had agreed upon them. This model can be adopted in other relevant issues regarding collaboration between field practice and academic research.

This article introduced the Creative Design Process (CDP) and the creative thinking scale (CTS). The CDP is aimed at assisting pupils in documenting the design process. The CTS could be used as a guideline for teachers during their tutoring and for pupils during the development of creative solutions to problems. The findings showed that pupils learned to document their design process according to the CDP. Finally, teachers turned into better tutors after they became familiar with the CTS.

The implementation of the CTS concerning the outcomes of the CDP has important consequences for the professional development of teachers and for the development of pupils' skills. Teachers can use the CTS as the goal of their teaching. If the CTS is introduced together with the CDP to pupils, they can develop their competencies according to various learning styles. The methodological assessment used in this study during the intervention program with the teacher and during the contest with teachers, senior teachers and researchers can be used in other science and technology domains. The contest was also found to be a useful instrument to enhance collaboration between researchers and teachers and among schools. This research could add a relevant body of knowledge to the assessment of technology education.

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Perceptions and Practices of Technology Student Association Advisors on Implementation Strategies and Teaching Methods

W. J. Haynie, V. W. DeLuca, and B. Matthews

Though still small, the co-curricular student organization, the Technology Student Association (TSA), has had a significant impact on the technology education profession. As the profession evolved from the Industrial Arts of the 1960s to become today's Technology Education (TE), the student organization has changed with the times too. TSA began as the American Industrial Arts Student Association (AIASA) and celebrated its 25th anniversary in 2003. Advocates claim that TSA activities have had significant impact in shaping the TE curriculum and also help to promote curricular integration with other disciplines (Peterson, Ernst, Blue, Taylor, & Estler, 2004). Growing from less than one-third of one percent of the students enrolled in industrial arts courses who were involved in AIASA (reported as 21,600 of 7 million by Applegate in 1981) to over 200,000 TSA members in 47 states today (Honor, 2004), the membership of the organization has increased nearly tenfold. In 2003 approximately 6,000 TSA members were elementary school children (Honor, 2004). TSA is an important facet of the technology education movement.

Proponents consider TSA to be more than simply another extracurricular activity—in its best form it is truly co-curricular and helps a TE program achieve learning and social goals for its students. Still, research on related extracurricular activities has meaning for interpretation of this study. Much of the research on extracurricular activities has focused on the relationship of participation with students' emotional and academic development. Haensly, Lupkowski and Edling (1986) concluded that extracurricular activities provide an important context for social, emotional, and academic development. The beneficial effect of student organization participation on academic performance was also supported by Camp (1987) who found that it produced a positive contribution to student achievement. Some recent findings also support the claim that students learn subject matter information while engaged in TSA activities (Peterson, Ernst, Blue, Taylor, & Estler, 2004).

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Related findings showing positive impacts of extracurricular activity involvement include social and personal development enhancement (Carter & Neason, 1984); a relationship between VSO (Vocational Student Organization) participation and results on scales of personal development (Townsend, 1981); higher self-esteem among participants (Collins, 1977); enhanced self-concept (Yarworth & Gauthier, 1978); increased social status among peers (Spady, 1970); leaning gains outside of school classtime hours (Haynie, 1983), and greater satisfaction with school (Nover, 1981). These early studies provide evidence of the many benefits of student participation in extracurricular activities, but a recent report (Camp, Jackson, Buser, & Baldwin, 2000) cautioned that some of the research supporting the perceived benefits of student organizations was weak and perhaps flawed. Lankard (1996) noted that some of the claims of the benefits of VSO participation may be overstated and more research is needed. Still, Taylor (2004) demonstrated positive effects of TSA activities on problem solving and creativity among students. More research on these issues is clearly needed.

Though there were several studies examining achievement and socialization of students prior to 1990, no studies were found which examined the effect of student organizations on teacher-student interaction in a laboratory environment. With the evolution of a new self image for technology education, it is important to determine the effects of co-curricular and extra-curricular activities and organizations on the total technology education program.

A study conducted in 1989 surveyed TSA advisors to find their perceptions concerning characteristics of technology education programs with a TSA component and the relationship between participation in co-curricular organizations and the teaching methods used by TSA technology teachers (DeLuca & Haynie, 1991). The study reported here sought to undertake an exact replication (as nearly as possible) of that work with the additional inclusion of a few items on current issues, replacing outdated ones from the previous investigation. Except for inclusion of those new items in order to investigate some learning activities and teaching approaches that have recently become more common than they were in 1989, the methods and instruments were nearly identical. The original study was conducted at the 1989 TSA National Leadership Conference and reported in the *Journal of Technology Education* in 1991 (DeLuca & Haynie). To provide a longitudinal dimension to the work, careful attention was given to maintaining consistency of the instrumentation, sampling technique, and general methodology in the current study.

Methodology

Sample

The sample for this study consisted of TSA advisors in attendance at the 2003 National Technology Education Student Association Leadership Conference in Orlando, Florida, June 23-28, 2003. Each school participating in the conference was required to have at least one advisor in attendance. The survey was conducted during the Advisors' Meeting midway through the conference. Two-hundred copies of the instrument were distributed and they were collected at the door as attendees left the meeting. This approach insured maximum participation and resulted in the receipt of 192 usable response forms, a response of 95%.

Instrumentation

A 48 item questionnaire was developed by the researchers for this study. Responses were marked directly on the survey instrument. The instrument was developed by expanding and updating the 33 item instrument used in the previous survey (DeLuca & Haynie, 1991). To the maximum extent possible items remained exactly the same to facilitate direct comparisons between the findings of both surveys and enabling a longitudinal aspect to this work. The first nine items were designed to measure the characteristics of the participants' technology education program and the ways in which they implement their student organization chapters. Specifically, items asked the respondents when and where TSA functions were conducted and assessed TSA advisors' implementation of TSA activities as part of the instructional curriculum. Item 9 required advisors to select, from among eight choices, the term that best described the type of lab in which they teach.

The next 33 items were used to identify the frequency of use of various teaching methods and learning activities. These items used a five point Likert-type scale, ranging from Most Frequently (A) to Never (E). Missing responses were ignored in all cases. Four items requested advisors' perceptions concerning the impacts of the national Standards for Technology Education and the accountability movement, including mandated standardized testing. To insure total anonymity, the only demographic data collected included the state of residence of the respondent and whether the school setting was urban, rural, or suburban. The last item allowed for any comments the respondent wished to make. The format of the instrument was a single sheet printed on both sides and folded to form a four-page pamphlet just over 5 x 8 inches in size with 20% "white space" to give it a professional look and prevent it appearing overly burdensome to the respondent. This was the same format as used in 1989 study except that this time the respondents marked answers directly on the instrument instead of on a separate response sheet. The stems of all of the substantive items are presented in the tables within this article.

Data Analysis

The collected data were analyzed with SAS (Statistical Analysis System) software. Frequency and percent tables were generated for each item and comparisons were made to the same items from the 1989 survey. For each item requiring a Likert response, numeric values from 5 (most frequently) to 1 (never) were assigned to the responses and a mean score was calculated. These means were rank ordered for further investigation.

Findings

The results of the survey were analyzed to describe the characteristics of technology education programs that had a TSA component, to identify and classify teaching methods used, and to make comparisons with the 1989 data. Since the national conference at which the survey was conducted was held in Florida, it would be expected that there might be higher representation from that region of the country. Another factor contributing to this parochialism is the large number of TSA programs in the southeast. This suspicion was confirmed via Item 47 which divided the nation into four regions using the Mason-Dixon line and the Mississippi River as axes. The representation levels from those regions were: Northwest, 6%; Northeast, 15%; Southwest, 25%; and Southeast, 46%. This may limit the degree to which one can generalize the findings, but the information should still be helpful to the profession. Demographic data also revealed that, of the schools included, 16% were urban, 41% were rural, and 38% were suburban, with 5% not reporting.

Characteristics of TSA Enhanced Technology Education Programs

The responses to Items 1 through 8 are shown in Table 1. All respondents claimed to have an active TSA chapter—which is logical since the respondents were attending a national TSA conference.

Table 1
Responses to Items 1 through 8

Item No.	Stem	Yes % (*n*)	No % (*n*)	N. A. %	Yes % 1989
1	Active TSA chapter	100 (192)	0 (0)	0	100
2	Chapter meetings after school	84 (161)	14 (27)	2	73
3	Meetings in activity periods	47 (90)	44 (85)	9	53
4	Co-curricular approach	16 (31)	78 (149)	6	35
5	State adopted/approved course names	73 (140)	14 (26)	13	88
6	State adopted curriculum	81 (156)	7 (13)	12	84
7	TSA events used as basis of activities	70 (135)	25 (48)	5	NEW
8	Name “Technology Education” represents programs well	85 (163)	11 (21)	4	90

Item 2 revealed that 84% of the advisors indicated that meetings and activities were held after school. Activity periods during the school day were used by 47% (Item 3), indicating that some teachers conduct TSA activities/meetings at both times. The comparative data from 1989 shows that more after school and fewer activity period meetings are used today. The co-curricular approach in which class officers conduct meetings during each class, as advocated and used frequently in other VSO's (Vocational Student Organizations), has fallen in popularity in TSA from 35% to 16% since 1989.

Most of the advisors (73%) teach courses which are named in state adopted curriculum guides (Item 5). Additionally, 81% indicated that their curricula closely follow the state guidelines (Item 6), indicating little change since 1989.

A new Item 7 (replacing an outdated one from the earlier survey) found that 70% of the advisors actually use TSA competitive events as the basis for class learning activities. In Item 8, 85% of the respondents indicated that they are pleased with the name "Technology Education" for our programs. This rate of approval was down slightly from the 90% positive response to this item in 1989.

Item 9 asked advisors to classify their laboratories by type. In 1989, "unit laboratories" (woods, metals, drawing, etc.) were still in use by half of the teachers and 10% of the teachers reported they used "manufacturing" labs. In the current survey, only 14% of teachers still use "unit laboratories" and less than 1% employ "manufacturing labs." Now the most often used labs are: "Modular Lab" (31%), "Integrated 'General Shop' Labs" (17%), and "Other" (16%). Of the systems labs popularized in the 1970's and 1980's, only the "Communication Lab" (13%) appears to be in current use.

Teaching Methods

Items 10 through 42 concerned implementation of various teaching strategies. Items 34 through 42 were the new items added in this study—all of the other items in this section were exactly the same as in 1989 to allow meaningful comparisons. A five point Likert-type scale was used to determine the relative frequency of use for each technique. Ranked results on these 33 items, along with their current and 1989 means, and their previous rankings appear in Table 2. Results were analyzed to determine changes in frequency of use of the various teaching methods.

Computers have become the hallmark of the modern technology education laboratory. All of the items from the 1989 survey which concerned computers used by teachers and students had significantly higher ratings in the current sstudy. See items 32 (rank 1st), 33 (2nd), 31 (3rd), 29 (6th), and 30 (9th). Each of these computer related items were ranked among the top 10, while none of them did in 1989. Additionally, three other applications of computers not considered in 1989 now ranked 13th, 14th, and 19th.

Demonstrations are still very popular methods of teaching as shown by their 5th place ranking and the high percentage (75%) of teachers who use them frequently or most frequently. However, demonstrations had ranked 1st in 1989 and were used often by 93% of the teachers. "Lecture-demonstrations" are also

Table 2
Rank ordered responses to Items 10 through 42

Rank	Item #	Item Statement	Mean	1989 Rank	1989 Mean	*p*	Significance
1	32	Computers used by teacher to prepare materials	4.46	12	3.32	.0001	*
2	33	Computers used by teacher for clerical chores	4.39	14	3.21	.0001	*
3	31	Computers used BY STUDENTS for lab activities or study	4.34	11	3.38	.0001	*
4	40	Problem solving activities	4.23	New			
5	12	Demonstrations	4.04	1	4.32	.0015	*
6	29	Computers for presenting information	3.97	19	3.08	.0001	*
7	24	Individual projects	3.93	4	3.92	.91	NS
8	22	Group projects	3.89	6	3.64	.026	*
9	30	Computers for demonstrations	3.87	20	3.01	.0001	*
10	17	Individualized instruction	3.80	3	4.05	.023	*
11	21	Lab experiments	3.79	7	3.61	.189	NS
12	13	Lecture-demonstrations	3.76	2	4.07	.0042	*
13	35	Computers for drawing and design (CAD or CADD)	3.75	New			
14	34	Computers for simulations	3.70	New			
15	25	Teacher designed/assigned projects	3.64	10	3.38	.0296	*
16	10	Lectures of 10 to 25 minutes	3.53	5	3.67	.278	NS
17	14	Discussion (teacher led, class participatory)	3.45	8	3.55	.328	NS
18	18	Small group discussions	3.36	13	3.21	.199	NS

Table 2 (continued)
Rank ordered responses to Items 10 through 42

Rank	Item #	Item Statement	Mean	1989 Rank	1989 Mean	*p*	Significance
19	36	Computer-based modular instruction.	3.34	New			
20	20	Student peer tutors	3.28	16	3.12	.174	NS
21	38	Inquiry-based learning	3.23	New			
22	26	Student designed/selected (free choice) projects	3.19	9	3.46	.036	*
23	42	Library or internet research papers or presentations	3.17	New			
24	41	Written assignments over 1/2 page	3.12	New			
25	28	Discovery method	3.10	21	2.93	.201	NS
26	16	Traditional media (films, slides, TV)	3.10	18	2.97	.217	NS
27	27	Group designed/selected projects	2.98	15	3.19	.09	NS
28	39	Service-based learning	2.65	New			
29	15	Seminar (student led, teacher primarily observes)	2.57	23	2.55	.876	NS
30	37	Modular instruction which is NOT computer-based	2.57	New			
31	23	Mass production (line production)	2.42	17	3.12	.0001	*
32	19	Role playing	2.35	24	2.45	.45	NS
33	11	Lectures of over 30 minutes	2.04	22	2.68	.0001	*

used by 57% of the teachers. "Lecture-demonstrations" ranked 12th in the current study as compared to a ranking of 2nd in the previous study and their actual frequency of use has declined from the 80% reported in 1989.

The third highest ranked item in 1989 was Item 17, which indicated that individualized instruction was then used frequently or more often by 74% of the teachers and nearly all of them (99%) used it at least sometimes. Today, though, there has been some decline as "individualized instruction" is used frequently by 60% of teachers and ranks 10th—only 2% of the respondents reported never using this technique.

Items 10 and 11 (ranked 16th and 33rd) show that lectures, when used, tend to be short in length. Use of short lectures (Item 10) has not changed significantly since 1989, but long lectures have significantly dropped all the way to the bottom of the rankings. In Item 14, most teachers reported that they use "discussion (teacher led, class participatory)" to some extent. The ranking for this item was 17th and it found that only 8% use discussion "most frequently," but nearly all teachers (99%) use it at least "sometimes."

Among "big losers" in the rankings, "Mass production (line production) projects," which ranked a respectable 17th in 1989 dropped nearly to the bottom of the list (31st rank) with a significantly lower mean in the current investigation. Role playing (Item 19) ranked last in 1989 and still ranks near the bottom at 32nd.

Though there were some slight shifts in positions (partially due to the inclusion of nine additional items in the current study) several items remained relatively unchanged. These included "Individual projects" (Item 24, rank 7th), "Lab experiments" (Item 21, rank 11th), and "Student peer tutors" (Item 20, rank 20th).

Items 34-42 were added to the survey for this investigation. These were included so that future studies may track the implementation trends of learning activities and teaching techniques currently advocated for technology education or evolving in many other disciplines of education. Noteworthy among these are "Problem solving activities" (Item 40, rank 4th), "Computers for drawing and design" (Item 35, rank 13th), and "Computers for simulations" (Item 34, rank 14th). Library and written assignments (Items 42 and 41) ranked low at 23rd and 24th. Item 39 (ranked 28th) found that "Service-based learning" has not been adopted with enthusiasm in technology education and non-computer based modular instruction was the lowest ranked of the newly added items, ranking 30th.

On the last page of the instrument, four additional new items sought TSA advisors' perceptions concerning the national Standards for Technology Education and standardized testing for accountability purposes. Item 43 found that most of the advisors feel informed about the standards. In Item 44, the majority of teachers (83%) indicated that the Standards are appropriate and 78% claimed that the Standards enhance their programs (Item 45). Item 46 probably only applies to advisors in those states using high stakes accountability testing, but thus far 73% of the advisors already feel that their programs are being "stifled" by standardized testing. These data are reported in Table 3.

Table 3
Responses to Items 43 through 46

Item No.	Stem	% (*n*)	% (*n*)	% (*n*)	% (*n*)	%	*M*
43	To what degree do you feel that you are knowledgeable about the national Standards for Technology Education?	29 (56)	53 (102)	11 (22)	2 (3)	5	3.17
44	To what extent do you feel that the national Standards for Technology Education are appropriate in their current form?	36 (69)	47 (91)	7 (14)	0 (0)	10	3.32
45	To what degree do you feel that your program is enhanced by your efforts to reflect the national Standards for Technology Education?	34 (66)	44 (84)	13 (24)	1 (1)	9	3.23
46	To what extent do you feel that your program is stifled by the accountability movement in education and/or mandated standardized testing?	27 (51)	46 (88)	19 (36)	3 (5)	6	3.80

Discussion

The importance of computers and computer based activities in the current TE (Technology Education) curriculum is evident in these findings. Computers are used much more frequently and in more ways by both teachers and students now than they were in 1989. Problem solving activities are employed in many TE classes and they should (if designed appropriately) provide a good basis for curricular integration with other disciplines in the schools. Despite the increased number of computers and modular instructional units in use since 1989, traditional techniques familiar to the industrial arts labs of the 1950's and 60's are still evident at a high rate, including demonstrations, individual projects, and lab experiments.

There was a change in the type of activities students are doing in the classroom. Problem solving activities ranked highest; this is as expected given the nature of TSA competitive events. The use of individual projects remained unchanged but there was a significant increase in the use of group projects. There was a significant decrease in the use of student designed/selected projects and a significant increase in teacher designed/assigned projects. These results are consistent with TSA events being used as a basis of activities (Item 7). The mass production or line production activities that were such an important and visible hallmark of the Industrial Arts Curriculum Project and other curriculum projects of the 1970's and 80's showed a significant decrease, along with the laboratories designated to support technology systems or clusters such as manufacturing and transportation. Likewise, some change in teaching methods is evident. Demonstrations, lecture demonstrations, individualized instruction, and lectures over 30 minutes decreased significantly. With 70% of the teachers reporting that they use TSA events as a basis for activities, associated changes in teaching and classroom activities are evident.

The negative findings include a decline in utilization of the co-curricular approach in which each class has its own TSA officers who basically manage the class with guidance from the teacher. This approach has been shown to be very effective in other disciplines with co-curricula vocational student organizations, such as the Future Farmers of America and the Vocational and Industrial Clubs of America. In the absence of this co-curricular approach, technology teachers are not realizing opportunities to ease their own lab management burdens while helping students gain leadership and social skills. Another noteworthy negative finding is that library and Internet research papers and written assignments of over half a page in length ranked in the bottom third of the activities and techniques considered. With the movement in the profession toward increased curricular integration and leaders in other disciplines calling for writing across the curriculum, it seems out of step for TE classes not to require more and longer written and research assignments. Likewise, service-based learning is being advocated by many leaders in education and TE has wonderful potential for its implementation. However, few teachers are implementing this technique.

The fact that "lectures of over 30 minutes" ranked last among the techniques is viewed as positive—evidently students are still "doing" more than they are passively listening, even if the nature of the activities have changed in the cognitive direction in the last decade. With increasing pressure from end-of-course testing in some states and efforts in place to include new topics in the curriculum about which some teachers may not feel adequately informed, one might fear that teachers would resort more to lectures rather than retain faith in the "learn by doing" philosophy that has long been so basic to the profession. Thankfully, that does not appear to be happening at the current time, but future research efforts should track any potential changes.

Conclusions and Recommendations

Change in classroom approaches reflects the nature of TSA competitive events which are hands-on problem-based activities. TSA teachers also feel somewhat or highly knowledgeable about the Standards for Technological Literacy and their programs are enhanced by those standards. A great deal has changed over the past 14 years. Those changes exhibited by TSA teachers show progress toward standards and problem-based learning taught in a computer rich environment. The "learn by doing" approach remains the primary teaching method in TE, but the actual learning activities experienced by the students have changed to reflect the evolving curriculum. It is recommended that teacher educators help pre- and in-service teachers develop balanced approaches with activities that match the topics under study by their students. Teachers should analyze their approaches and the activities they assign to their students to insure that the best approaches are being employed. Future investigations should continue to track change in the profession and help identify noteworthy trends. In addition, research should compare TSA enhanced programs with TE programs which do not have TSA, investigating whether or not teachers differ in their instructional approaches. TSA and the activities it sponsors provide rich learning opportunities for students as well as making the public aware of high quality technology programs.

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Coming to Terms with Engineering Design as Content

Theodore Lewis

With the publication of standards for teaching, learning, and the inculcation of technological literacy (International Technology Education Association, 2000), technology education in the United States has made a significant leap forward toward greater acceptance as a valid school subject. Standards represent content terrain claimed by a community of practitioners, and once stakes are put down, it is left to adherents to move in seeking title. It is doubtful whether we will witness a rush towards bio-technology or medical technology, new areas in the standards that do not naturally issue from our accustomed traditions. But for design there will be great interest since this is a content area over which the field has long toiled. *Design* is arguably the single most important content category set forth in the standards, because it is a concept that situates the subject more completely within the domain of engineering. Four of the 20 standards address the question of design directly. Standard 8 deals with the "attributes of design;" Standard 9 with "engineering design;" Standard 10 with "trouble shooting, research and development, invention and innovation, and experiment in problem solving; and Standard 11 with the "design process."

It is not inconsequential that the foreword heralding the standards is authored by William Wulf, in his capacity as President of the National Academy of Engineering. This is a significant benediction for a subject whose advocates have for the past decade or so been of the view that its acceptance by the public and by the dominant academic culture of schools turned on the degree of rapprochement that could be worked out with the science as well as the engineering communities. The Project 2061 curriculum standards acknowledged the common epistemological ground shared by science and technology as school subjects, embodied in the designed world (American Association for the Advancement of Science, 1993; Johnson, 1989). With ties with science thus formalized, engineering was but a step away. The sentiments expressed by Bensen & Bensen (1993) foreshadowed what appears now to be a significant opportunity for the field of technology education to lay claim to aspects of engineering as part of its curriculum purview. Arguing that the subject should

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assume the name "Engineering and Technology," they wrote: "it is imperative that we engage the engineering profession, the companies that employ them, the universities that educate them, and the associations and accreditation bodies that set the standards and benchmarks for them, to become involved in bringing the curriculum into the twenty-first century" (p.5). These sentiments are now shared by important professional engineering bodies, such as the Institute of Electrical and Electronics Engineers (IEEE), as can be seen in the strategies set forth by this body at its "Technological Literacy Counts" conference. The prevailing sentiment was that cementing ties between the subject and the field of engineering had become a high priority, such ties to include joint curricular endeavors (Institute of Electrical and Electronics Engineers, 1998). Writing from the vantage point of the National Academy of Engineering, Pearson & Young (2002) emphasized the need to make engineering accessible to all citizens through the inclusion of engineering design in the curriculum.

The climate for engagement with engineering is now inviting; technology education is being viewed favorably as a credible means of advancing the goal of technological literacy for all, and a means by which students can gain insights about and interest in engineering careers.

This article addresses the challenges posed by engineering design as a content area of technology education. What adjustments will technology teachers have to make in their approach to teaching and learning when they teach design as engineering in response to the new standards? How faithful to engineering as practiced must their approach be? There is already some advocacy in the literature that greater attention will need to be paid to mathematics and science, where these subjects underpin design. Cotton (2002) proposed that mathematical theories should be applied to design in technology education classrooms, and that students should be encouraged to use mathematics to predict the outcomes of their designs. Neumann (2003) suggested that students should spend more time engaged in research and re-design activities, as is the case in British schools. Roman (2001) encouraged an integrative approach to design that incorporates mathematics and applied science, in keeping with the cross-cutting nature of engineering. Afoot here is a discourse on curriculum integration that raises challenging questions for the field, including whether technology teachers as normatively trained are equipped to venture into the teaching of engineering design.

Westberry (2003) has laid groundwork for the issues that are to be taken up here, by calling attention to alternative models of design, and exploring the challenges inherent in teaching it across the grade levels. This article necessarily pays attention to approaches to design, but it especially also examines design pedagogy within engineering education. How is design taught to engineers? What logics underpin such teaching? The structure is as follows: (a) the design/problem solving literature of technology education is reflected upon, (b) the question "what is engineering design?" is explored, (c) approaches to the teaching of design in engineering education are examined, (d) reflections on engineering design follow, and finally (e) conclusions and implications inherent in coming to terms with engineering within technology education are set forth.

Design and Problem Solving in Technology Education

Design has been a focus in the practice and literature of technology education, often embedded within discourse on problem solving. Its prominence has increased with the shift in American curricular thinking about the subject from a disciplinary to a process focus (e.g. Savage & Sterry, 1990). De Luca (1991) provided a survey of problem solving approaches employed in technology education classes, surmising that design activities teach students how to think, once the learning environment created by the teacher is conducive to creative behavior. Johnson (1988) examined the problem solving literature of technology education and proposed a model for research comprised of three components, the solver, the solving process, and the problem. He suggested that the model could be used to investigate problems relating to trouble shooting or designing. Employing the model empirically he found differences between expert and novice problem solvers (Johnson, 1989; Johnson & Chung, 1999). In one study, the primary performance difference between novices and expert trouble shooters was found to be the quality of information acquired and the quality of the hypotheses they generated in solving problems (Johnson, 1989). In a subsequent study, Johnson & Chung (1999) used think-aloud problem solving methodology to compare the cognitive performance of an experimental group over a comparison group. The approach helped learners evaluate trouble shooting hypotheses, and potential faults in a system.

One dimension of the design/problem-solving literature has focused upon the critical question of the professional development of teachers. Zubrowski (2002) examined the integration of engineering and science via a three-phase pedagogical model comprised of (1) exploration during which students mess about preliminarily, (2) introduction of a standard model, and (3) improvement of the preliminary model. This pedagogical model was used as the backdrop for designing engineering projects. He found that the approach fostered the teaching of science as well as interdisciplinary collaboration among teachers. Koch & Burghardt (2002) described teachers' involvement in action research, as they developed design challenges for their students. Here too, design was said to have fostered curriculum integration.

Another focus of the design/problem solving literature has been upon learning in the elementary grades. Denton (1994) examined reactions of children to design and technology simulation activities aimed at teaching them about industry and economics. The motivation of students improved as they made connections between simulations and regular design work. Foster & Wright (2001) found that children increased their technological capability and technological knowledge, having participated in design and technology activities. Gustafson, Rowell & Guilbert (2000) examined children's awareness of structures, finding that they can work out regimes for testing and evaluating the strength of a structure represented on paper.

Addressing an area of need in the teaching of design and problem solving, Custer, Valesey, & Burke (2001) validated an instrument for assessing student learning. The work was premised on the view that problem solving can be reduced to a set of discrete, observable behaviors that can be captured via appropriate rubrics. Assessment in technology education is still an undeveloped aspect of the subject, and when associated with the teaching of design it will pose its own peculiar challenges. Just what are students expected to learn when they are taught design, and how is their knowledge to be ascertained? How does the context of engineering alter the way in which we might approach the assessment of design?

Orienting the conversation on design toward creativity, Lewis, Petrina, & Hill (1997) suggested that problem finding has been a missing dimension of the design/problem-solving literature, contending that it is just as important in technology education classes to have children pose problems as it is to have them solve them. The centrality of problem finding (or problem posing) in design/problem solving can be seen in seminal contributions to the creativity literature, notably Getzels, 1982; and Getzels & Csikszenthmihalyi, 1976; and Wertheimer, 1968. In his *Productive Thinking*, Wertheimer (1968) set forth that "the function of thinking is not just solving an actual problem, but discovering, envisaging, going into deeper questions." Mumford, Reiter-Palmon, & Redmond (1994) contend that problem posing contributes to creative problem solving, and that it is inherently a cognitive activity. The new engineering thrust of technology education will require that problem posing be given at least as high a priority as problem solving. Children will have to be taught to imagine – to think like engineers, making observations in the world around them, and finding areas of need for which technological design would be central to the solution.

What is Engineering Design?

Since design stands at the core of both craft and engineering traditions, its meaning and usage in technology education is not always settled. Where craft design draws on aesthetics primarily, engineering design has both creative as well as rational dimensions (e.g. Cross, 2000). It is necessary that the conception of engineering design that becomes normative as technology education teachers interpret the standards be an authentic depiction of design as it is conceived and practiced by engineers. This section of the article is in this vein.

Nature of engineering design

While engineering design is an agreed upon cognitive activity, there are nuances in how it is conceptualized. One dominant view is that design is the essence of engineering, an aspect of human ingenuity upon which the competitiveness of countries depend (Koen, 1994). Koen (1985, p. 50) has written further that engineers work "at the margin of solvable problems," proceeding from the known to the unknown. They work under conditions of change, uncertainty, and resource constraints. Koen explains that unlike scientists who proceed within the framework of scientific laws, engineers employ heuristic laws to arrive at design solutions. Heuristics do not guarantee solutions, but they reduce the search time in solving a problem.

Koen devised a taxonomy of heuristics that can be employed in engineering design, comprised of the following elements: (a) *simple rules of thumb* (e.g. one gram of uranium yields one megawatt of energy); (b) *factors of safety* (not trusting pristine calculations and adding a compensatory factor—such as to the calculated wall thickness of a pressure vessel); (c) *attitude* heuristics (such as the maxim that the engineer should always be ready to give a back-of-the-envelope answer to peculiar engineering questions); (d) *risk* heuristics (e.g. approaching new problems by making only small changes in what has worked; and (e) *resource allocation* heuristics (including allocating sufficient resources to the weak link in the design).

Pahl and Beitz (1996) write that the main task of engineers is to "apply their scientific and engineering knowledge to the solution of technical problems, and then optimize those solutions within the requirements and constraints set by the material, technological, economic, legal, environmental and human-related considerations" (p. 1).

Beyond the technical, design can also be situated in the realm of the *psychological*. It is creative, requiring grounding in mathematics and science, as well as in domain specific knowledge and experience. Design has systemic aspects, requiring optimization of given objectives within partly conflicting constraints. These authors identify types of designs, goals, and methods. Types include (a) *novelty*…new tasks and problems needing original design, which must proceed through all phases (b) *adaptive*…established solution principles held constant but the embodiment is adapted to changed requirements; (c) *variant*…sizes and arrangements of parts are varied within the original design parameters ("design within fixed principle"). Goals include (a) optimization of function, (b) minimization of cost, (c) aesthetic considerations, (d) ergonomic considerations, (e) and minimization of weight. Solution methods include (a) *conventional* (e.g. literature search), (b) *intuitive*, inclusive of preconscious or subconscious ideas or insight or flash, brainstorming, or using analogy, and (c) *discursive*…use of design catalogs or systematic combinations.

Reflecting upon everyday commonplaces (such as the aluminum soda can), Petroski (1996) emphasizes the importance of *failure considerations* in engineering design. He writes that 'What distinguishes the engineer from the technician is largely the ability to formulate and carry out the detailed calculations of forces and deflections, concentrations and flows, voltages and currents, that are required to test a proposed design on paper with regard to failure criteria." p.89. If designing a bridge, the engineer must calculate the load that individual structural members can safely carry before they buckle or come apart, and how much deflection can be allowed at the center of the bridge. Engineers can test a design on the drawing board or computer. Where failure conditions are indicated, the design is modified. Petroski writes that obviating failure is a design principle. Failure considerations extend beyond the technical to the environmental or aesthetic.

Reflection

As can be seen above, engineering design is viewed as a creative endeavor that proceeds in an environment of uncertainty, from known condition to unknown. Design solutions are framed by constraints, such as cost and safety. Though engineers are constrained by nature, and must rely upon mathematics and scientific principles, they differ from scientists in the extent to which they draw upon heuristics rather than scientific laws in making design decisions.

Design processes

Engineers rely on a variety of strategies when they design. Cross (2000) noted that these strategies continue to evolve. He pointed to a trend toward the formalizing of the design process. According to Cross, the new approaches can be classified into two broad groupings, namely creative methods and rational methods. Included in creative methods are brainstorming, synectics (such as analogical thinking and bisociation (see Koestler, 1969), and enlarging the problem space through dialectics—pitting an idea against its opposite. Rational methods involve breaking a problem into sub-problems, then arriving at sub-solutions. He identifies a general process comprised of seven fundamental design stages, inclusive of clarifying objectives, establishing functions, setting requirements, determining characteristics, generating alternatives, evaluating alternatives, and improving details (p59). Cross makes clear that rational processes and creative processes are complementary, both aiming to improve the quality of design decision-making. Rational approaches to design do not preclude creativity.

The design process is not linear. Hinrichs (1992) pointed out that c*onstraints* may change in the course of the design, requiring the engineer to switch problem space, thereby making new solutions possible. Components of the design may change as well as the structure. Design is not a discrete engineering phase, Hinrichs points out, rather, that it is continuous through significant portions of the lives of projects. Middendorf & Engelmann (1998) concur noting that engineering design is an iterative process requiring numerous decisions. They argue against an omnibus design method, contending that "By the very nature of design, the process used will be different, depending on the type of system or device to be designed, the state of the art, the supporting personnel and equipment available, the number of units likely to be made, and so on" p.8. Still, they set forth the outlines of a general approach comprised of the following:

1. problem definition, inclusive of recognizing a need, and the state of the art.
2. problem evaluation…need analysis, specifications, feasibility
3. synthesis...study of patents, development of alternate design concepts, determination of the most creative step

4. analysis…mathematical models, computer simulations, test of physical models, optimization of design
5. communicate and manufacture p.11

They write that in the process of design if little scientific information is available then an intuitive approach might be needed. Where such information is available, as in the sizing of boilers, well defined mathematical procedures will be available. Similar general approaches to engineering design have been set forth (e.g. Cather, Morris, Philip & Rose, 2001; Dominick, Demel, Lawbaugh, Frueler, Kinzel & Fromm, 2001).

French (1992) set forth aids to design, beginning with the use of rough sketches and simple calculations to develop insight into unfamiliar problems. He suggested that the approach to solution ought to be diversified. The designer should proceed stepwise, remembering that ideas do not always arrive in their final form. Initial failures should not be rejected. French recommended seizing the essence of problems by increasing the level of abstraction during solution. One design solution approach he recommended is the use of combinative methods in which design functions are listed and matrixed against all possible solutions by which each can be done, the final product being a morphological chart that offers design options. The best combination of solutions is then determined (p.12). In a later work, French (1999) set forth a design schema that parallels a more generalized process approach as set forth by Cather et al, 2001; Dominick et al, 2001; and Middendorf & Engelmann, 1998. The process begins with a need. The client is then questioned and the designer thereby arrives at a clear statement of problem. The problem statement generates broad solutions. The *conceptual design* stage follows, the approach being open ended, searching for schemes to solve the problem. There are tradeoffs between conflicting goals, with the focus being more on function than on form. French contends that this is the phase of the most striking improvements, where engineering science, practical knowledge, production methods and commercial considerations come together. At this stage the designer cannot predict how subsystems might react, or what options may have to be ruled out because of local conditions. Possible concepts or design schemes are then fleshed out such as selecting and sizing major subsystems. Rules of thumb are employed, followed by detailing and refining.

Dym (1994a) contends that the key element in engineering design is *representation*. A design problem may require a multiplicity of representations, such as those needing analytic physics-based models, geometric or visual analysis, economic or quantitative models, or verbal statements not easily captured by algorithms. Such requirements could be statements of function or intent. He agrees that the design process is evolutionary in nature, with choices to be made and alternative paths to follow as it unfolds. The process may include (1) clarifying the requirements of the client, (2) identifying the environment, (3) modeling the behavior (can the device be assembled?), (4) identifying the constraints (manufacturing, marketing, economic), (5) testing and evaluating the proposed design, (6) examination of whether there is a more economic or efficient design, and (7) documenting the completed design for the client (p.22).

Hubka (1982) identified similar general steps as French (1999) and as set forth in Dym (1994a), but he writes that the process of engineering design also includes a set of "strategic maneuvers." They include (a) *iteration*, strategies used when a direct solution is not possible and assumptions must be made in order to proceed onward to a solution; (b) *abstraction*, ignoring unimportant steps and concentrating on important ones; (c) *concretization,* moving from rough preliminary solutions to fine tuned ones; (d) *improvement*, starting from a feasible solution, using criticism to improve it (p.34). Mullins, Atman & Shuman (1999) included an analysis phase comprised of the creation of mathematical and scientific models to study each alternative.

Cross (2002) provided insight into design by looking at the processes employed by three experts: designers respectively of racing cars, sewing machines, and bicycle luggage carriers. He found that though they functioned in different domains, these designers shared common general approaches to their work. All three adopted a systems approach to design, rather than a more restrictive approach. All relied upon first principles in their work. For example, the luggage designer focused upon triangulation to achieve rigidity and stiffness, while the racing car designer focused upon the physical forces that acted on a car. Finally, all three explored the problem space from particular perspectives that were dictated by the nature of the design situation and personal motivations, including the desire to provide pleasure to the product user. Cross found that the designers' behaviors could be explained by the concept of the reflective practitioner. He further pointed out that while each operated on a set of common approaches, it was not possible for them to switch between domains, since domain-based expertise required extensive training.

Reflection.

This brief examination of engineering design, its nature and processes, allows tentative comparison and contrast with design as traditionally conceived within technology education. One area of commonality seems to be that there is rough agreement on a general design procedure, inclusive of problem clarification, generation of possible solutions, evaluation of solutions, deciding on a solution, and representation and detailing of it. Beyond areas of commonality is a clear zone of divergence, beginning with assumptions about the knowledge base required by the design engineer. It is evident that engineering designers must posses a combination of scientific, mathematical, and domain-specific knowledge. In addition they must possess *engineering design content knowledge*, consisting of prior experience, knowledge of heuristics, ability to work within tight constraints, ability to make trade-offs, ability to change design in the course of a project, ability to design for manufacturability, and ability to conform to the demands of the customer. Engineering designers must sort through conflicting goals as they seek to optimize function. The starting point of design may vary and may include re-design

Design in Engineering Education.

Despite general agreement in the literature that design lies at the core of engineering, how it should be approached in the engineering curriculum at the university level is still unsettled. Dym (1994b) observed that design is still an area of contention, with some in the engineering community believing it lacks definitive content and rigor, while others contend that creativity cannot be taught. In a special issue of *Engineering Education* devoted to the teaching of design, authors examined the tensions. McMasters & Ford (1990) expressed the view that schools of engineering should understand that engineering and design are synonymous. Noting that conceptions of design were not stable, they wrote of difficulties surrounding its inclusion in the college engineering curriculum. West, Flowers & Gilmore (1990) lamented that design and build projects get low priority in the curriculum, with the tensions centered on the questionable value of hands-on learning.

Peterson (1990) wrote that unlike engineering science, "Design…is not a science and has no rigorous rules for progression. Both as taught and as practiced, it is almost invariably interdisciplinary. Design projects typically specify only desired performance, leaving task definition and solution synthesis to the student." p. 531. He cautioned that under prevailing pedagogic conditions, too little attention is paid to "creative questioning" p. 530.

In the years since this special issue, design in the engineering curriculum has become an area of heightened focus. The ensuing literature provides glimpses into how engineering schools seek to provide their students with design competence. The approaches vary; in some programs design is offered as a capstone course and in others as a freshman course.

Harris & Jacobs (1995) described a capstone-project approach to design teaching. The method they adopt includes five phases, namely, conceptual design, analytic design, detailed design, construction and testing, and competition. These authors distinguished between problem solving and design. They add that whereas typical engineering problem solving provides all necessary information to solve a given problem, real design problems are open ended.

Wild & Bradley (1998) proposed an engineering program featuring a *concurrent approach to design*. Concurrent design moves design away from a linear approach to problem solving. The basic design process is supported by theories including (a) *Design for Assembly* (DFA), which provides production information at the stage where alternative conceptual designs are being considered; (b) *Design for Manufacture* which is part of the detailed analysis of the best conceptual design; (c) *Quality function development*, which adds customer information to the process; (d)*Failure Modes and Effects Analysis* (FMEA), which enhances product reliability by heading off failure at early stages of design, (e)*Taugushi Method Analysis*, which quantifies cost at production and at consumption point; and (f)*Rapid prototyping*, which is used to connect the design to the prototype. These authors divide the process of design into conceptual and analytic phases.

Mullins, Atman & Shuman (1999) found that one semester of engineering design led to improvement in the sophistication with which students approached the design process, but not in the quality of their solutions. They used techniques such as verbal protocols to document and measure students' engagement in the design process. Petroski (1998) described an approach to teaching a freshman engineering design course in which students were required to improve the Gem paper clip. He writes that while conventional wisdom says that first-year students do not have the requisite analytic tools gained through engineering design courses, it is possible to challenge them meaningfully through his approach. The course required no prerequisite, yet provided a multidimensional experience and challenge, including exposure to the patent system. The gem paper clip has faults of function and form, allowing students to see "the nature of design, which is how to solve a problem of function while not introducing more new problems, i.e., by keeping undesirable consequences to a minimum" p.445. Petroski wrote that design always entails compromises and tradeoffs, thus:

> What students learn through the exposure to a score or more of paper clip patents . . . is that while patents may fairly present a new design as an improvement over the prior art, with each new design also come compromises. To make a paper clip that grips better, one risks having one that that also tends to rip papers more aggressively upon removal. To make a paper clip that has a greater capacity than a standard Gem, more wire must be used and so the clip must be more bulky and more expensive to manufacture. (p. 446).

Pace (1999) described a structured approach to teaching mechanical design principles in an engineering foundations course at a British university. The course adopts a *product analysis* approach**.** Students are presented with an artifact that must meet the following basic criteria: (1) be the embodiment of mechanical principles, (2) perform a simple-to-understand, interesting function, (3) be available in alternative designs for comparison, and (4) be testable for functional performance using desk-top apparatus. An interesting aspect of Pace's account is the importance he attaches to the fact that English students are exposed to Design and Making (or technology education) in the school curriculum ahead of their attending university and seeking a degree in engineering. Students are aided by having taken this subject in their high school years.

Koen (1994) examined the teaching of design, concluding that the behaviors of practicing engineers are not necessarily the same as those of engineering students. He hypothesized that design is really a set of behaviors. Experts can give a quick answer if that is needed, based on experience. Thus, "To teach engineering design is to develop a strategy for changing the repertoire of design behaviors of the student to that of an acceptable professional engineer using principles of behavior modification" p.194. In this vein, Gerhard (1999) described a behavior modification approach to teaching engineering design.

Of considerable interest because of its K-12 implications, Carroll, (1997) described a project in which elementary school children were introduced to engineering through a bridge building exercise. Materials were prefabricated by engineering students, but the children engaged in the actual building. The project allowed possibilities for integrating the curriculum, with aspects of the bridge helping the teaching of geometry, reading, social studies, and physics.

Design in engineering classrooms has been the basis of empirical examination. Napper & Hale (1999) reported on an assessment project aimed at determining the effectiveness of capstone design courses in selected engineering programs. The data were video-tapes of seniors presenting their prototypes and final designs. The projects were evaluated on a set of design criteria specified by ABET (Accreditation Board for Engineering and Technology). An important outcome of the project was increased awareness of the difficulties inherent in assessing student designs.

Koehn (1999) reported on a study aimed at determining how undergraduate and graduate students and practicing engineers from one university rated the importance of selected ABET criteria as aspects of the civil engineering curriculum. The criteria were (a) Engineering Codes and Standards, (b) Economic Factors, (c) Environmental Effects, (d) Sustainability, (e) Manufacturability (constructability), (f) Ethical Considerations, (g) Health and Safety Issues, (h) Social Ramifications, (i) Political Factors, and (j) Legal Issues. Two of the constraints, Environmental Codes and Standards, and Manufacturability (Constructability), were highly rated by both the students and practitioners. Rated low were Social Ramifications and Political Factors.

Reflections on Engineering Design

A first important lesson learned from looking at design within engineering and engineering education is that while it is central to the discipline, there is not consensus as to how it should be treated in the curriculum; and indeed, whether it should be included at all is still a matter of debate. One unsettled question is whether design is a rigorous enough area of engineering to warrant curriculum treatment. Where it is included, there is some disagreement as to whether it should be taught early or late in programs, or whether it should be infused across the curriculum.

However, there is general agreement on what constitutes design in engineering, how designing should proceed, and what role domain knowledge plays. There is also agreement that design is a fluid process which can be segmented into stages. Some of these stages, such as need identification, invention, and evaluation of alternative designs are well known to technology education. The distinction that French (1999) makes, though, between *conceptual* and *analytic* stages of design is extremely useful, showing the importance of contextual and engineering science knowledge, as well as inventiveness, in design decision making. More importantly, this division of design phases may suggest a way in which technology educators can delimit their work.

French (1999) wrote that the conceptual stage of design "is the phase where engineering science, practical knowledge, production knowledge, production methods, and commercial aspects need to be brought together, and where the most important decisions are taken" p.3. This way of conceiving of the stages of design appears to be approaching consensus proportions (e.g. Harris & Jacobs, 1998; Middendorf & Engelmann, 1998; Wild & Bradley, 1998). As indicated above, Harris & Jacobs (1995) reported that conceptual design and analytic design were key phases of their pedagogic approach when teaching a mechanical engineering design course. The object was to create an egg-carrying buggy powered by an internal combustion engine. The conceptual design phase focused on arriving at a suitable design. They wrote:

> Immediately following the completion of the conceptual design, work commences on the analytic design to prove the functionality and endurance of the overall device and its components. Analytical designs typically commence with the establishment of overall speeds and loading, static and dynamic. These are translated into component loading, stresses and deflections. Depending on the component, thermodynamics and heat transfer analyses may be required in the determination of loading and stresses. The stresses are compared against the strength data for the initially selected component materials, and if necessary, alternate materials may be selected to meet yield and fatigue resistance. (p. 346)

Upon reflection, it would appear that conceptual design is within the normal purview of technology education. Analytic design poses a challenge. It is the point at which we arrive at a black box, when children construct the tallest tower, or design the fuel-efficient vehicle without understanding why. The question that arises is whether we would have done our part as a field if we delimited our role to conceptual design. One view emerging within technology education is that we could go further, into analytic design. Thus the underlying science and mathematics should be taught to students, to help them make predictions about their designs (e.g. Cotton, 2002; Roman, 2001). This line of thinking has its merits, and could be an area of much discussion, with implications for how the content knowledge of technology education teachers must be considered.

For clues to how we might think about this question we could reflect upon the debate of whether design should be taught to first-year engineering students. The question arises because in the first year, students would not yet have been grounded in the engineering sciences. Petroski's (1998) response to this is that it is possible for first-year engineering students to learn "the nature of design" through his paper-clip re-design problem. Students also have opportunity to learn first hand "the nature of engineering drawings, materials, manufacturability, economics, ergonomics, etc." (p. 446). Some of his students even devised experiments to test their solutions. All get an opportunity to critique their own designs. Petroski's point is that even without an analytical design phase, his first year design course achieves significant learning objectives.

Pace's (1999) description of the use of product analysis as a means of teaching design is worth noting because the approach seems to be in keeping with established technology education traditions. Students take apart machines and tools routinely. Those same acts can now be the basis for their learning of engineering design, though they will come to the same limit as with conceptual design, when technical analysis is required.

Conclusions and Implications

Design in technology education corresponds in important ways with the design tradition of engineers. In both cultures, the open-ended problem in which the designer ventures from the known to the unknown is considered the prime challenge. Both come to the conceptual stage of design, where options are evaluated, taking into account design parameters. The engineering culture, more than the technology education culture, pays much attention to customer needs, to the question of trade-offs and constraints, to code requirements, to failure considerations, to manufacturability, and to the underlying science and mathematics. In practice, engineers rely on a memory bank of solution strategies that have worked in the past; they also call upon heuristics where quick estimations are needed.

The above examination of design from the perspective of the engineering profession, including insights from engineering education, provides the backdrop for ensuing comment on the challenges and opportunities for technology education as practitioners strive to come to terms with engineering. The comments are framed in terms of (a) what are the boundary limits of technology as it seeks to adopt engineering design as content? (b) how should content knowledge supportive of design be considered? (c) what should technology education teachers know to be able to teach design competently? and (d) what are the new possibilities for research?

Boundary limits

One challenge for technology education is how can it interpret engineering design authentically? This issue is settled with respect to conceptual design, which clearly has informed design teaching in schools. The issue of analytic design, however, remains open. How should the field deal with the limit of analytic design? One defensible option would be for technology education to accept this limit, and to view conceptual design as the extent of its domain, in much the way that Petroski (1998) approaches the teaching of design to first year engineering students. The focus is not on calculations, but on learning the essence of design, including critique of design, the role of trade-offs, team-work, invention, etc. A second possible solution might be to approach analytic design in a limited way by including a set of completely worked out engineering design cases in the instructional repertoire of schools. A third option might be to adopt a collaborative approach to design, where technology teachers team with mathematics and science teachers, and with practicing engineers, in the teaching of design. This strategy would allow both analytic and conceptual aspects of design to be realized.

Content Knowledge

How much domain knowledge should technology students possess before it is assumed that they can competently tackle design problems? This question has to be given greater consideration now, because of links to engineering. Design in technology education often shows itself in the form of a space to be spanned by a bridge, a tall tower to be built, or a structure that will bear load. Students compete to see which individual or group has built the tallest tower, or has constructed the longest bridge, or has gotten its structure to bear the most weight. Often the teaching episode ends when a winner is identified, without students' gaining understanding of the reasons behind the success or failure of their attempts. That kind of rote approach to design misrepresents and grossly oversimplifies the task of the engineer, and perhaps more critically, it inhibits student creative performance, a critical aspect of which is the possession of requisite content knowledge (e.g. Lubart & Sternberg, 1995).

Two scenarios that arise on the question of the importance of domain knowledge are (a) whether the intent is to teach just the generic *process* of design, or (b) whether it is to facilitate the solution of a design challenge within a particular domain. In the former case, it is conceivable that the teacher could proceed without consideration of domain knowledge. He/she could rely upon commonplaces (every-day materials or artifacts) about which the *functional knowledge* of students is assured, and could teach in a domain-independent manner. In the latter, students will need some degree of requisite pre-knowledge, depending upon the domain, whether electronics, materials, or construction. Since design in technology education could proceed along the two lines suggested above (content independent and content dependent) there is need in the discourse of the field to distinguish between them. Each approach has an important and peculiar purpose.

Teacher Competence

Just what should constitute the repertoire of technology education teachers if they are to teach design competently? Consistent with comments above with respect to student learning, the implications for teachers are that they would need at minimum to possess some measure of domain knowledge in the main disciplinary areas of the standards (such as manufacturing, construction or transportation). Teachers should also possess some agreed upon competence level in mathematics and science. There are implications here for the re-tooling of both pre-service and in-service teacher development programs. Moreover, teachers would need grounding in design practice, competence that they could acquire through industrial internships.

Research Possibilities

Design offers many opportunities for inquiry in technology education, beginning with the challenges that attend its teaching and student learning. Such inquiry could span areas such as effective methods of assessment of student learning and effective teaching strategies. A more complete conception of the possibilities will emerge once the field works out an appropriate conceptual framework. Ultimately, such a framework can conceivably be informed by discourse streams such as multiple intelligences, learning styles, creativity, and cognition (e.g. Cropley, 1997; Houtz, 1994; Sternberg, 1990).

Conclusion

This article has considered the adjustments to be made within technology education for the field to come to terms with engineering as content. These adjustments have been shown to span not just curriculum and instruction but also inquiry and teacher preparation. Adjusting to the design imperative will be a more realizable proposition if technology educators seek to improve their competence by immersing themselves in environments where engineering design is practiced, and by actively collaborating with such practicing engineering designers. The higher the degree of collaboration that can be forged with practicing engineers, the more likely it will be that teachers will overcome initial tentativeness, and that they will teach design authentically. The result will be a greater chance that students will have authentic design experiences.

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Gender-based Preferences toward Technology Education Content, Activities, and Instructional Methods

Katherine Weber and Rodney Custer

Prominent U.S. economists and educational leaders have argued that citizens must become technologically literate to maintain economic growth (Bybee, 2003; Colaianne, 2000; Greenspan, 1997). All students of both genders need to acquire the skills necessary to become consumers capable of critically assessing the technologies they use, resulting in the ability to make more informed decisions.

One of the key problems confronting educators in the SMET disciplines (science, mathematics, engineering, and technology) is the disproportionate lack of involvement of females. Females' lack of participation has been attributed to curriculum content that is biased toward males' interests (Sanders, Koch, & Urso, 1997). Others (Shroyer, Backe & Powell, 1995) attribute females' lack of interest to pedagogical approaches rather than to the inherent nature of the subject.

One significant challenge is culturally-grounded gender stereotyping, which has a substantial influence on children's self-concepts (Witts, 1997). In a variety of ways, the media, peers, and adults communicate and reinforce gender-based stereotypes (Martin, Eisenbud, & Rose, 1995). For example, toys have a powerful influence on what children perceive as appropriate for boys and girls. Toys designed for boys tend to be highly manipulative or electronic whereas girls' toys are less likely to be manipulative or have interchangeable parts (Caleb, 2000; Sanders 1997). Girls' toys also tend to feature interpersonal interaction, such as dolls, which encourage the development of social skills and relationships (Caleb, 2000). Sanders, Koch, and Urso (1997) assert that girls who are not exposed to toys that encourage scientific, mathematical or technological thinking are less likely to develop an interest in related subject areas at school.

In a study of the interest patterns of middle school students, Shroyer, Backe, & Powell (1995) found that socially relevant topics were more appealing

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to girls, in contrast to boys who were more interested in how things work. They also found that girls were more interested in topics related to the environment, people, and the application of this knowledge to social conditions than were males.

Given the historically disproportionate involvement of males in industrial arts and technology education, male perspectives and interests tend to pervade the technology education curriculum (Sanders, Koch, & Urso, 1997; Welty, 1996). The *Standards for Technological Literacy* represent a positive movement in addressing this concern, since the structure of the standards provides for diverse ways of developing curriculum and representing the interests of both genders. Curriculum developers in technology education need to be informed by research and theory designed to comprehend “women’s ways of knowing” if they hope to effectively recruit and retain women and girls into the study of technology (Belenky, Clinchy, Goldberger, & Tarule, 1986; McIntosh, 1983; Welty, 1996; Zuga, 1999). Shroyer, Backe, & Powell (1995) indicate that the study of environmental and social technologies may be more appealing to girls than the study of industrial technologies.

Pedagogical considerations are also critical to sound gender-balanced curriculum design. Research has found that there are instructional methods, learning styles, and interests that can be characterized as distinctively female (Brunner, 1997; Jacobs & Becker, 1997; McIntosh, 1983; Rosser, 1985; Zuga, 1999). Additionally, curriculum materials need to connect in meaningful ways with students’ prior experiences and the world in which they live (Zuga, 1999).

Teachers are encouraged to construct knowledge from students’ experiences (Belenky, Clinchy, Goldberger, & Tarule, 1986; Jacobs & Becker, 1997). While this is important for all students, it is particularly important that teachers and curriculum designers in the SMET disciplines attend to the experience base of female students. Students often feel that content lacks relevance to their lives (Markert, 2003; Jacobs & Becker, 1997; Sanders, Koch, & Urso, 1997). It is important to connect students to content through their life experiences (Wills, 2000). Rather than continually using traditional tools, material, or examples to demonstrate technological concepts, teachers should use examples with which both genders can identify.

Females prefer collaboration over competition (Chapman, 2000; Fiore, 1999; Jacobs & Becker, 1997; McIntosh, 1983; Rosser, 1990; Sanders, Koch, & Urso, 1997). This is consistent with contemporary trends in technology education, where the historic use of individual projects is shifting toward small group work. However, contemporary practice also employs the substantial use of student competitions. For example, although the Technology Student Association (TSA) and the Technology Education Collegiate Association (TECA) feature collaborative activities, considerable emphasis is placed on the competitive aspects of the events.

Purpose and Methodology

The purpose of this study was to identify the types of learning activities, topics, and instructional methods in technology education that are preferred by middle and high school females and males. Specifically, three questions were posed:

1. Which activities, related to the study of technology, are most preferred by females and males at the middle school and high school levels?
2. Which curriculum content topics, related to the study of technology, are most interesting to females and males at the middle school and high school levels?
3. Which instructional methods, related to the study of technology, are most preferred by females and males at the middle school and high school levels?

A descriptive design was employed using two surveys designed by the researchers. One survey identified the interest preferences of students toward activities in technology education, while the second identified students' interest preferences toward content topics and instructional methods in technology education.

The population consisted of students enrolled in middle school and exploratory level high school technology education classes in Wisconsin. A purposive, stratified sample of consisting of eleven technology education programs (which had at least forty five minutes of contact time each day) was selected with the assistance of a representative from the Wisconsin Department of Public Instruction to ensure gender representation as well as coverage across urban, suburban, and rural areas. Within the eleven programs that agreed to participate, six were middle school programs (three were urban, one was suburban, and two were rural) and five were high programs (two were urban, one was suburban, and two were rural). Within the six middle school programs, one of the seven participating teachers was female. Within the five high school programs, one of the nine participating teachers was female.

To ensure gender representation, technology programs with high female enrollment were selected. Most school districts in Wisconsin require at least one technology education class for all middle school students; therefore, the study's middle school sample was gender balanced.

The sample size for the study was based on the Krejcie and Morgan's (1970) formula. A total of 348 middle school students and 311 high school students participated in the study.

Instrumentation

Two instruments were developed. The ***T**echnology **A**ctivity **P**reference* (*TAP*) Inventory consisted of a set of activities typically used in contemporary technology education classes. These were gleaned from a variety of carefully selected technology education curriculum materials with the assistance of state supervisors.

To ensure a broad representation of activity types, two conceptual frameworks were employed. First, activities were coded into context standards categories corresponding with Standards 14-20 in the *Standards for Technological Literacy* (ITEA, 2000). The second framework, generally corresponding to the types of activities involved in technological literacy as described in the *Standards*, as well as *Technically Speaking* (Pearson & Young, 2002), was comprised of designing, making, utilizing, and assessing.

Three technology educators with substantial experience with standards-based curriculum development reviewed the activities. They were instructed independently to rank order each activity according to its relevance, authenticity related to student experience, and distribution across each of the activity types. The final version of the *TAP* contained 56 activity items. Each item was rated on a 1-5 Likert-type scale according to level of student interest (from Very Interesting to Not Interesting at All).

The second inventory, **T**echnology topics and **I**nstructional methods **P**reference Inventory (*TIP*) focused on standards-based content topics. Topics were identified by reviewing the descriptive narrative, standards, and benchmarks of the *STL* (2000). The topics compiled for each of the twenty standards in the *STL* (2000) were submitted to the panel of technology education curriculum experts for rating. Rating criteria included representativeness of the standards category, coverage, and concreteness. The two topics receiving the highest composite ratings were selected for the instrument for a total of forty items (2 per *STL* standard). As with the *TAP* instrument, each item was rated on a 1-5 Likert-type scale according to level of student interest.

In addition to the content topics, the *TIP* also contained a list of instructional methods typically used in technology education programs (e.g., making projects, designing solutions, engaging in debate and discussion, etc.). These methods were identified through the literature review and were selected to be representative of gender preferences.

A pilot test was then conducted with a group of middle and high school students to ensure the instruments' clarity, students' understanding of directions and individual items, and ease of administration. Some minor modifications were made to the administration protocol and instruments as a result of the pilot test, primarily to ensure clarity. (Note: Additional detail about the instrument development process is presented in Weber, 2004).

Data Collection

Technology teachers from the selected programs were invited to participate in the study. After each teacher agreed to participate, informed consent and assent forms were distributed to students and returned to each teacher prior to administration. To ensure administration consistency, the researcher traveled to each school site to administer the surveys. The instruments were introduced with a full explanation of how to rate the items. To avoid fatigue from completing both instruments in the same class hour, a five-minute break was provided between the administration of the two instruments.

Data Analysis

The independent variables were gender and grade level. The dependent variables consisted of level of interest responses to the activities and topics. The activities and topics variables were analyzed separately using two-way factorial analysis of variance by gender and grade level. A descriptive analysis was also conducted to identify the activities and topics students rated most and least interesting. A crosstabs analysis provided a mechanism for analyzing both independent variables simultaneously.

The final step in the analysis focused on pedagogical preference, where students were asked to rank order their preference on three separate sections that included: instructional methods, instructional approaches to activities, and instructional groups. The rank order of each section was identified using a composite rank score, calculated by multiplying the number of people who ranked the item by the rank number. Separate composite ranking scores were computed for each independent variable to facilitate gender and grade level comparisons. Each of the three pedagogical item sets were then placed in rank order using this composite score, with the lowest score representing the most preferred method and the highest score being least preferred.

Findings and Discussion

Activity Preferences

A two-way factorial analysis of variance was conducted to compare gender and grade level differences for the activity variable. At the composite level (the entire activity data set), no significant differences were found between the interest ratings of females and males (see Table 1). At the subcategory level, however, significant gender differences were detected regarding interest in activities that involved *designing* and *utilizing*. Consistent with the literature, females rated the *design* activities more interesting than did males, while males preferred *utilizing* types of activities (Welty & Puck, 2001). No significant differences were detected between genders in the *make* and *assess* dimensions.

Table 1

Male and Female Interest Preferences toward Activity Categories

Activity	Sample Size		Mean		SD		
Category	M	F	M	F	M	F	*p*
Composite[a]	386	271	2.83	2.86	.72	.66	.321
Design	385	271	2.85	2.64	1.16	.69	.030*
Make	385	271	2.73	2.70	.80	.73	.878
Utilize	387	271	2.54	2.80	.70	.73	.000*
Assess	386	271	3.26	3.31	.86	.80	.518

Note. Lower numerical values indicate higher levels of interest and higher numerical values indicate lower levels of interest.

[a]Composite: comprised of responses toward all activities

* $p < .05$

The activities selected for the inventory had similar appeal to both genders. This is important since the activities were specifically selected to represent contemporary technology education. This suggests that the field is doing a reasonably good job of developing activities that are equally appealing to both genders. This study also suggests that curriculum developers appear to be doing a relatively good job of selecting and developing activities representing an appropriate gender balance.

Females' preference for *design* and males' preference for *utilizing* is generally consistent with gender stereotypes. This is particularly true when the *design* activities include a focus on problem solving or socially relevant issues. By contrast, males typically are attracted to a variety of building activities, which involve the use of machinery and tools. Traditional industrial arts activities have often tended to de-emphasize the *design* aspects of *making*, with students often working from existing project plans. It is possible that the increased emphasis on design in contemporary technology education courses could provide some balance between this *design* and *make/utilize* dichotomy and make technology education activities more appealing to both genders.

Responses to the four activity categories were also examined by grade level. Analysis of the composite activity set detected significant grade level differences (see Table 2). Middle school students rated the composite of activities more interesting than did high school students. Significant differences were also found with the *design*, *make*, and *utilize* activities. The relatively low interest in *assessing* activities is consistent with the culture of technology education, which tends to favor applications-oriented activities over reflection and analysis.

Table 2
Middle School and High School Interest Preferences Toward Activity Categories

Activity Category	Sample Size MS	Sample Size HS	Mean MS	Mean HS	SD MS	SD HS	*p*
Composite[a]	345	310	2.78	2.92	.73	.65	.007
Design	346	310	2.62	2.92	.79	1.16	.002[*]
Make	345	311	2.60	2.84	.79	.73	.000[*]
Utilize	347	311	2.59	2.71	.76	.67	.004[*]
Assess	346	311	3.28	3.29	.88	.77	.994

Note. Lower numerical values indicate higher levels of interest and higher numerical values indicate lower levels of interest.
[a]Composite: comprised of responses toward all activities
[*] $p < .05$

During the instrument development, a deliberate attempt was made to select activities that would appeal to both middle and high school students. The activities were also judged to be representative of contemporary technology education activities. Consequently, it was somewhat surprising that middle school students rated the activities more appealing. One reason for this outcome could be that the technology education profession may be doing a better job of developing curriculum materials for the middle school than for the high school. This finding may reflect a coherence of curricular focus at the middle school level, which has yet to be achieved at the high school level, where programs tend to range from vocationally focused trade and industrial programs to engineering and pre-professional programs. Significant work remains to be done to conceptualize the discipline and curriculum materials for the high school level. This need is particularly pronounced at the advanced level, where the programs are diverse and where curriculum materials are scant and tend to be underdeveloped. The curriculum development challenge is further exacerbated in general by the problems associated with stimulating high school students' levels of interest in school (Rice, 1997; Roderick, 1993).

The data were also analyzed to identify activities that appeal and do not appeal to males and females. Several differences among males and females emerged. The top five activities rated interesting by females generally focused in the areas of communication or design (see Table 3). Consistent with the literature, females were interested in activities that support and facilitate communication and which are of social relevance (Jacobs & Becker, 1997; Markert, 2003; Sanders, Koch & Urso, 1997; Shroyer, Backe, & Powell, 1995). In striking contrast, males focused on transportation vehicles with an emphasis on utilizing and constructing. The interest in design-oriented activities was also less pronounced with males as was the use of computers to produce designs.

Table 3
Activities Rated Most Interesting

Female preferences at middle school and high school levels	***n****
1. Use a software-editing program to edit a music video	224
2. Using a computer software program, design a CD cover.	210
3. Design a model of an amusement park.	195
4. Design a school mascot image to print on t-shirts.	192
5. Design a "theme" restaurant in an existing building.	190
Male preferences at middle school and high school levels	
1. Build a rocket.	293
2. Construct an electric vehicle that moves on a magnetic track.	284
3. Perform simple car maintenance tasks on a car engine.	279
4. Program a robotic arm.	271
5. Design a model airplane that will glide the greatest distance.	268

[*] *n* = the number of students who rated the activity either "very interesting" or "somewhat interesting"

The activities were also examined for lack of interest patterns. One thread that spanned both gender and grade levels was a general lack of interest in agricultural related activities. This finding is striking since these areas are relatively new to technology education. Additional work remains to be done to develop materials that will stimulate interest in this emerging area. Another general pattern that emerged was a lack of female interest in construction activities. While this is consistent with the literature, the finding indicates that developing engaging construction-related activities for females remains a significant challenge for curriculum developers (see Table 4). It is also useful to observe that the activities in this section tend to coincide with pedagogical strategies typically employed by the traditional academic disciplines (e.g., debate, research, evaluate). This suggests that the pedagogical approach may have a significant impact on student interest beyond the inherent interest in any particular activity.

Table 4
Activities Rated Least Interesting

Female preferences at middle school and high school levels	***n*** *
1. Debate the advantages and disadvantages of using pesticides in agriculture production.	164
2. Design a new use for an agricultural product.	156
3. Research why different materials are used to construct buildings in various areas of the world.	156
4. Evaluate the energy efficiency of your home.	148
5. In order to make a recommendation for a bridge, assess the environment in the area where a bridge is needed.	144
Male preferences at middle school and high school levels	
1. Assess the risks of genetically engineered plants.	241
2. Debate the advantages and disadvantages of using pesticides in agriculture production.	212
3. Research methods used to recycle plastics into reusable materials.	203
4. Make a simple working model of a stethoscope.	200
5. Maintain a green house to harvest food year round.	200

* *n* = the number of students who rated the activity either "not very interesting" or "not interesting at all"

Topic Preferences

The second major focus of the study was to explore patterns of student interest in technology education topics derived from the *STL*. This is important since the inherent interest in topics could differ from topic-related activities. Well developed activities can potentially engage students in topics that may be of little inherent interest. The study's design included both topics and activities in an attempt to explore these dynamics. This two-dimensional approach is also important because the technology education field has historically emphasized activities, often with a corresponding de-emphasis on content and conceptual development (Custer, 2003). In this respect, the *STL* represent significant progress in identifying an appropriate conceptual framework for the content of the field. Appropriate curriculum development must select and develop activities that will deliver and reinforce content rather than the other way around (Wiggins & McTighe, 1998). Thus, exploring student interest patterns for both topics and activities will begin to develop a base of information for curriculum developers. Teachers need to know which areas to emphasize as they select and develop activities.

A two-way factorial ANOVA was conducted to compare gender and grade level differences related to technological topics. At the composite level, significant differences were found between males and females, with males rating the topics significantly more interesting than females. Significant gender differences were also found with specific *STL* content areas including The Nature of Technology, Design, Abilities in a Technological World, and The Designed World, with the males rating the topics more interesting than females (see Table 5). These findings are generally consistent with cultural stereotypes, where males tend to be more interested in technology-related topics than females. It is interesting to note the lack of significant differences for the technology and society category. This is consistent with research indicating that females are interested in technology topics that are socially relevant (Caleb, 2000). No significant grade level differences were found across the major *STL* categories.

Table 5
Male and Female Interest Preferences Toward Content Standards

Activity Category	**Mean**		**SD**		
(male n = 366, female n = 249)	**M**	**F**	**M**	**F**	***p***
Composite[a]	3.09	3.35	.91	.84	.001*
The Nature of Technology	3.24	3.59	.99	.91	.000*
Technology and Society	3.31	3.51	1.04	1.00	.067
Design	2.91	3.18	.97	.90	.001*
Abilities for a Technological World	3.05	3.33	.98	.97	.002*
The Designed World	2.94	3.16	.92	.88	.010*

Note. Lower numerical values indicate higher levels of interest and higher numerical values indicate lower levels of interest.
[a]Composite: comprised of responses toward all activities
* $p < .05$

The topics rated most interesting were compared by gender. A striking degree of similarity was found, with four of the top five topics receiving high ratings by both genders. The points of difference are consistent with the findings in the activities component of this study, with females indicating high interest in design and males indicating interest in repairing products (see Table 6). While females tend not to prefer utilizing types of activities (see Table 1) when compared to males, females rated two communications-oriented utilizing topics as most interesting. This is consistent with the literature, which indicates a female preference for communication and interpersonal interaction (Caleb, 2000). This has important implications for gender-balanced topic selection in technology education.

Table 6
Topics Rated Most Interesting

Female preferences at middle school and high school levels	*n*[*]
1. Using computers to communicate	174
2. Cloning	150
3. How video materials are developed to communicate a message	140
4. Robotics	120
5. Characteristics of design	112
Male preferences at middle school and high school levels	
1. Robotics	247
2. Using computers to communicate	232
3. Cloning.	221
4. How to repair products	198
5. How video materials are developed to communicate a message	171

[*]*n* = the number of students who rated the topic either "very interesting" or "somewhat interesting"

Some interesting patterns emerged with respect to the topics rated as least interesting (see Table 7). Both genders were least interested in topics generally associated with ethical and societal values, which could signal a general lack of interest in these types of topics among middle and high school level students. At the same time, this finding is perplexing given the potential impact of technology on critical social issues such as genetic engineering, information technology privacy, global resource distribution, and national security, this finding is somewhat disturbing.

Table 7
Topics Rated Least Interesting

Female preferences at middle school and high school levels	*n*[*]
1. The correct and safe use of tools and machines	161
2. How technology has improved agriculture	159
3. Ethical issues related to technology	154
4. How societal values and beliefs shape technology	139
5. How to reduce the use of nonrenewable energy resources	135
Male preferences at middle school and high school levels	
1. Ethical issues related to technology	195
2. How societal values and beliefs shape technology	188
3. How people decide to buy consumer goods	179
4. Ethical and social issues related to biotechnology	176
5. How technology has improved agriculture	176

[*]*n* = the number of students who rated the activity either "not very interesting" or "not interesting at all"

The general lack of interest in agricultural and biotechnology topics may be due to their relative newness in technology education. As the population demographics continue to shift from agricultural to urban areas, generating student interest in the agriculture-related topics may become increasingly challenging.

The pattern of topics rated least interesting by both genders is generally aligned with content that is somewhat new to the field and which may be perceived to be associated more with social studies topics than with technology. Given the importance of these ethical and resource distribution issues on a global scale, the field will need to find ways to generate additional student interest on these topics at a local or community level.

Instructional Approaches

The final component of the study focused on instructional approach preferences, which represents a third major element of the student preference complex (along with activity and topical preferences). As with most educational and behavioral science issues, student motivational and interest pattern dynamics are complex and multi-dimensional. Specific to gender-based student interest patterns in technology education, it is quite possible that engaging instructional approaches could stimulate student engagement with topics that previously held little interest. For this study, instructional approach data were gathered and analyzed in three different sets: general instructional approaches, activity-specific approaches, and instructional grouping preferences.

The rank order preference patterns for general instructional approaches were similar for males and females (see Table 8). Students who typically enroll in technology education classes are attracted to the types of projects that they will be engaged in, so it is not surprising that doing projects was ranked "1" by both genders. Somewhat inconsistent with research, however, was the high

Table 8
General Instructional Approaches

	Females		**Males**	
	Rank Sum	**Rank**	**Rank Sum**	**Rank**
Doing projects	641	1	939	1
Competitive Activities	888	2	988	2
Collaborative activities	1020	3	1349	4
Online learning	1063	4	1343	3
Debate	1090	5	1603	7
Stations in computer lab	1175	6	1464	5
Discussion	1200	7	1742	8
Independent study	1257	8	1588	6
Lecture with discussion	1614	9	2136	9
Lecture	1877	10	2458	10

ranking of competitive activities by females (preference #2). Research indicates that females are less interested in competitive activities than boys, preferring learning environments that nurture collaboration (Chapman, 2000; Fiore, 1999; Jacobs & Becker, 1997; McIntosh, 1983; Rosser, 1990; Sanders, Koch, & Urso, 1997).It is interesting that "online learning" and "stations at a computer lab" are ranked higher by females than "debate" and "discussion". This may have to do with the purpose of computer use. Females' interest increases if the computer is used as a tool to create something like a multimedia presentation, but not if the focus is on learning how to program computers (Brunner & Bennett, 1997, 1998). Consistent with the literature were the relatively low rankings of "debate" and "discussion" by the males (Welty & Puck, 2001). Also, both genders ranked "lecture" and "lecture with discussion" as the least preferred methods of instruction.

The rank order preferences toward activity-specific instructional approaches were essentially the same for both genders (see Table 9). Consistent with the literature, females ranked "exploring how well something works" as their least preferred approach; on the other hand, males' ranking it as their least preferred approach is inconsistent with literature (Welty & Puck, 2001).

Table 9
Activity-Specific Instructional Approaches

	Females		**Males**	
	Rank Sum	**Rank**	**Rank Sum**	**Rank**
Making a project	292	1	432	1
Learning how to operate or use something	555	2	703	2
Designing a solution to a given problem	624	3	818	3
Exploring how well something works	689	4	850	4

Table 10
Instructional Grouping Preferences

	Females		**Males**	
	Rank Sum	**Rank**	**Rank Sum**	**Rank**
Working with partners	386	1	539	1
Working in groups of three or more people	449	2	607	2
Working alone	619	3	758	3
Working together with the entire class	704	4	895	4

The rank order preferences of instructional groupings are the same regardless of gender or grade level (see Table 10), with both genders expressing a preference for small group work. This finding is generally consistent with the evolution in the field from the heavy traditional emphasis on individual projects to the contemporary emphasis on teamwork and group projects.

Implications and Discussion

The finding that contemporary technology education activities have similar appeal to both males and females is instructive. Even if the topics presented in the *STL* appear to be inherently more interesting to males, the selection and development of gender-balanced activities appears to overcome the differences in topical interest. While it may be extremely difficult to change cultural and gender-related stereotypes, it is possible that carefully selected and well-developed activities could stimulate female interest in topics about which they may have previously had little interest. This represents a positive challenge for curriculum developers.

A deliberate attempt was made to select activities for the instrument that would appeal to both middle and high school students. Consequently, it was somewhat surprising that middle school students rated the activities more appealing. One could speculate that technology educators are simply better at developing curriculum materials for the middle school than for the high school. Significant work remains to be done to conceptualize the discipline and its associated curriculum materials for high school students. This need is particularly pronounced at the advanced level, where the programs are quite diverse and where curriculum materials are scant and tend to be underdeveloped.

The extensive use of student competitions should be examined in more depth by the profession. While the findings of this research indicate support of competitions by females, this outcome contradicts previous research. Since technology education competitions tend to be conducted in teams, it could be that the collaborative aspects of the process enhance the appeal of competitions for females. It should also be noted that the participants in this study chose to elect technology education classes. Thus, the characteristics of these female "selectors" may differ from those who have not opted to take technology education classes. Regardless, given the emphasis on collaboration and the concerns about competition in the literature, this represents an important area of future research.

Females' preference for designing learning experiences and males' preference for utilizing learning experiences was consistent with gender stereotype research. Research indicates that females are more interested in design-oriented activities. This is particularly true when the design activities include a focus on problem solving or socially relevant issues. By contrast, particularly in traditional industrial arts classes, males have been attracted to a variety of building activities, which involved the use of machinery and tools. In many cases, traditional industrial arts activities have tended to de-emphasize the design aspects of making, with students often working from existing project plans. It is possible that the increased emphasis on design activities in contemporary technology education courses might provide some balance between designing and making/utilizing – which potentially makes technology education activities more appealing to both boys and girls.

The findings reflect that students are reluctant to expand their interests in content and activity types in the areas of agriculture, medicine and biotechnology. It could be that students who typically enroll in technology education classes have preconceived notions about the types of activities in which they will engage and that these expectations do not include medical, agricultural, and biotechnology related activities. This presents a challenge to curriculum developers who design activities in these new areas. Students' interest may increase if there are clear connections established between the skill and concept similarities in agriculture, medical, and biotechnology activities to activities found in familiar contextual areas. Additional research will be required to better understand these dynamics.

Recommendations for the Profession

Based on the findings, conclusions, and implications of this study, the following recommendations are suggested for future practice:

1. Additional research should be conducted to better understand the dynamics of student preferences for technology related topics, activities, and pedagogical approaches. Of particular importance is an understanding of the factors that are most important for female students.
2. Technology Education curriculum developers should intensify the use of research results of gender based studies to design and develop standards based activities that appeal to females. Particular attention should be placed on research conducted in the SMET areas of study (science, mathematics, engineering and technology).
3. The profession should invest substantial effort and resources into developing standards based curricula to deliver agricultural, biotechnology, and medical technologies with engaging and interesting activities. This will require collaborating with science teachers (particularly in biology and earth science).
4. The profession should invest significant effort into developing new resources focused on ethical and social issues consistent with the *Standards for Technological Literacy*. This is particularly important for technology teachers, many of whom have relatively little formal preparation in teaching social science oriented topics.
5. The profession should invest resources into conceptualizing and developing appropriate curriculum materials for upper level high school technology education programs. This is particularly important given the growing alliance with engineering.

6. The profession should invest in additional research identifying demographic preferences of students toward activities, topics, and instructional methods. Further refinement and use of the TIP and TAP inventories would assist curriculum designers in developing curriculum that is gender balanced.

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Book Review

Weimer, M. (2002). *Learner-centered teaching: Five key changes to practice.* San Francisco: Jossey-Bass/Wiley. $33 (hardcover), 258 pp. (ISBN 0-7879-5646-5). Excerpt available: www.josseybass.com

Reviewed by Patrick N. Foster

How many times have we heard (and probably told college students) that the difference between high-school and college was this: blame the teacher if a high-schooler fails—but a failing college student isn't the professor's responsibility? Maryellen Weimer doesn't buy this. That's not to say she absolves today's college students—whom she characterizes as passive, distracted, and extrinsically motivated—for poor performance. But, in *Learner-Centered Teaching*, she argues that professors are obligated to create an environment in which students and teachers share responsibility for learning.

Learner-Centered Teaching is not about changing the corporate university structure, or even about restructuring curriculum. For the most part, Weimer advocates changes to individual sections of individual courses by individual teachers. These changes are based on assumptions, both stated and implied, which run counter to prevailing practice. Among them are that:

- Professors and college students can "share power" (p. 23) in the college classroom.
- The theories and beliefs of "radical and feminists pedagogues" (p. 28) deserve our attention, careful consideration, and, in many cases, adoption.
- Professors should spend more time producing and consuming introspective research about college teaching and learning.
- A sweeping change to learner-centered teaching can be done without changing the professor's and students' roles in assigning grades (e.g., p. 90, 130, 144).

That teachers can functionally share "power" with students is a provocative assumption, and advocating such an orientation is equally provocative. But on the other hand, the book's title appears reasonable—what's wrong with a little "Learner-Centered Teaching?"

In fact, isn't good teaching, by its very nature, at least learner-*focused*? If an ideal K-12 technology program could be deduced from our literature over the past twenty years, it would probably have as much of a learner focus as practicable in this era of standards. The greatest impact of technology teacher

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educators like Donald Maley is probably the successful dissemination of this philosophy through college programs and into classrooms across the US and elsewhere.

It seems likely that many technology teacher educators model learner-centered teaching for pre-service teachers. At the college level, Weimer suggests taking a step beyond a Maleyian [Maleyesque?] junior-high classroom and involving students in text selection, syllabus construction, and content selection.

Organization

A little more than half of the text proper (Part One, Chapters 2-6) focuses on "what changes when teaching becomes learner-centered" (p. 21). To Weimer, there are five major changes: the balance of power, the function of content, the role of the teacher, the responsibility for learning, and the purpose and processes of evaluation (p. ix). The last three chapters (Part Two, Chapters 7-9) focus on implementing the changes Weimer advocates.

I found Part One to be the more compelling, perhaps due to Weimer's liberal use of anecdotal examples and research citations, both of which are woven seamlessly into the text. Much of Part Two felt like a reiteration of the foregoing material, at least until the book's final chapter.

The book also includes 55 pages of back matter: three appendices, including a sample course syllabus; references; and a detailed nested subject index. *Learner-Centered Teaching* is available as a .pdf file from online booksellers (for the same price as the hardcover), and the whole of Chapter 1, formatted as it is in print, can be read for free at the publisher's website.

Changing the College, One Classroom at a Time

Weimer acknowledges that ideally, students, administrators, and other stakeholders would accompany college teachers in transforming the culture of higher education. But until then, she proposes that professors, in their classrooms, make unilateral changes within their sphere of influence.

The first, and most fundamental needed change, she says, is to balance power in the classroom. Coupling personal experiences with her readings of feminist theory and cognitive psychology, she contrasts the "traditional power structures and the role of authority in the classroom" with "more democratic and egalitarian views of education that open it to the possibility of different kinds of learning" (p. 10). Weimer provides a framework for identifying power-sharing opportunities and for altering courses to take advantage of them. Some suggestions seem easy enough (like having students negotiate the course-participation policy), others oblique (such as not calling on students randomly even if the class is unresponsive), and some challenge the basis of the traditional teacher-learner relationship. Among the most surprising of the latter is to give students a significant voice in the selection of content.

I can picture the reactions of at least some of my colleagues here:

- We are preparing students to be teachers. What if they choose NOT to study the Standards for Technological Literacy, classroom management, and curriculum development?
- This is a lab class. We have procedures and safety rules that must be taught. Maybe this isn't the course to experiment with this level of student input.
- How can students choose the content when the content is beyond my control? In our state students must take Praxis II.
- Is this really what we want to model for our students? When they get their first teaching job, I don't want them asking teenagers what content to teach!

These potential concerns (some of which might have great merit upon closer inspection) are in addition to the more general objection, applicable to fields beyond technology teacher education, that the college professor has been hired to teach to the best of her or his ability—and that while some student input is healthy, letting the students make these decisions is an abdication of responsibility.

I believe Weimer, while acknowledging that professional fields might adapt her ideas to some degree, would nonetheless charge that teacher educators are too focused on content. She refers, at times humorously, to professors' "allegiance to content" (p. 47) and "the race to cover content" (p. 48). This seems to describe us well, although it does not address whether content may be more important in some fields than in others.

The second major change Weimer advocates—"that students need to be told less and discover more" (p. 12)—rings true, with two important caveats. First, some courses are prerequisites for others, provide content required for a licensing exam, or in some other way, have a special emphasis on content. Second, the subject being taught may have an influence on the way students learn; "It is more difficult to see how knowledge can be socially constructed in science, math, and engineering fields where there are more 'right' answers and much less disagreement about the status of knowledge" (p. 12). Weimer removes neither of these issues as an impediment to moving from a content-centered to a learner-centered classroom. The implication is that the balance of power should be corrected immediately, even if changing the function of content is slowed by curricular, political, or other facts of college life.

Changing either the teacher-student power balance or the meaning of content requires two further changes, Weimer says: teachers must "position themselves alongside the learner and keep the attention, focus, and spotlight aimed at and on the learning processes" (p. 76), and students, with faculty assistance, must develop "the intellectual maturity, learning skills, and awareness necessary to function as independent, autonomous learners" (p. 95). She is particularly adamant that college students become responsible for learning. Of course, if classrooms are to be learner-centered, and if learners are to share power with professors, the role of the student changes just as radically as that of the teacher or the content.

Professors and institutions share the blame with students for a culture in which learning is passive, Weimer says. And don't get her started on our "rule-based approaches" that function as "token economies" wherein students are only motivated to act if sufficient points are offered (p. 96-97)! "Development as an independent learner," she writes, "is not the inevitable outcome of formal educational experiences" (p. 16). The final major change Weimer proposes, in the purpose and process of evaluation, is part of the answer to promoting intrinsic learner motivation:

> …what students are most likely to learn in a course is directly related to what they are evaluated on. Evaluation is not just something used to generate grades; it is the most effective tool a teacher has to promote learning. (p. 17)

If this sounds safe enough, Weimer proposes linking assessment and learner empowerment in an even deeper way:

> Given the fact that faculty evaluate student work so entirely, the idea that students should be involved in the process strikes many faculty as a radical alternative. … Can they be involved in self-assessment activities without compromising faculty responsibility to certify what they know and can do at the end of the course? (p. 130)

As is her approach throughout the book, Weimer handles this issue first by acknowledging that the entire notion is "on the edge" or "radical" to college teachers and administrators (e.g., p. 130-131), then asking why it strikes us this way. She follows this with (usually empirical) research citations—for example, a meta-analysis of student self-assessment that found that such assessment, under certain circumstances, is highly correlated to faculty assessment. Finally, she provides examples of faculty who have tried the approach.

Applying Weimer's Ideas

As radical as many of Weimer's ideas are, it would certainly be possible to reengineer a technology teacher education course to include some of her recommendations. Take, for example, the lab teacher's concern: "This is a lab class. We have procedures and safety rules that must be taught."

Of course, no one is going to suggest that a teacher put herself or himself in legal danger by not teaching safety rules. But a manufacturing lab instructor could begin the course with a tour of the laboratory facilities and hand out several manufacturing curricula. The students could be given the responsibility for determining what equipment and processes to include in the course. This content selection could be overseen by the instructor, who would have opportunity to influence the choices if the need arose.

The same approach could be used in courses that in part prepare students for Praxis II. Students could be assigned to research the exam and identify which components would be appropriate, for instance, in a manufacturing course. Again, the instructor, as the resident expert, would exert influence when applicable.

Final Thoughts

Even though I have cited some of the more provocative examples from the book, much of the material in *Learner-Centered Teaching* would be agreeable to most teacher educators and technology educators. Then again, the book's audience appears to be professors who have had no formal training as teachers. Weimer's repeated chiding of professors for being unaware of the literature on teaching methodology, for example, suggests this. Teacher educators could agree with Weimer on every point and still not implement her ideas in certain classes on the basis that they are modeling K-12 teaching methods to prospective teachers.

Nonetheless, I offer this review not because I felt that the book needed a critique, but because I believe that the ideas Weimer presents could benefit technology teacher educators, even if we are not her primary audience.

Miscellany

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