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From the Editor

Branding the Horse We Are Going to Ride into the Green Pastures Ahead

In my career-long pondering about our field and where we are heading, I happened upon a book that caught my attention. The book is titled *No Logo* by Naomi Klein, written nearly ten years ago (1999). She discussed the evolution of corporate America, citing companies like Nike, Microsoft, Tommy Hilfiger, and Intel. She stated that, “What these companies produced primarily were not things, but *images* of their brands” (p. 4). “Some of today’s best-known manufacturers no longer produce products and advertise them, but rather buy products and ‘brand’ them” (p. 5). This caused me to think about what business do we think we are in, what business do we think we *ought* to be in, what business do *others* think we are in, and what business are we *really* in? These thoughts were inspired by the possible integration of the word “engineering” into the title of our profession, consideration of which is going on right now. In fact, ITEA Executive Director, Kendall Starkweather, reported the results of a survey that was recently conducted among the membership (Starkweather, 2008).

Consider IBM. Their brand in the form of the IBM letters and the familiar blue logo that goes with them is known throughout the world. My guess is that few these days even know that IBM is an acronym for the International Business Machine Corporation. Though they have tripped and stumbled a few times, my guess is that they could enter the power tool manufacturing business, for example, if they wished and have an immediate following of customers. Through their natural and planned evolution, they have become much more than a business machine company. In fact, the notion of business machines really does not fit them at all any more. Most recently they have poised themselves in “service science” and have supported some universities to establish a formal academic discipline in this area. Moreover, they state that “From a research and science perspective, we’re aiming to put service innovation on the same kind of systemic foundation as computer innovation” (http://www.ibm.com/ibm/think/, slide 25). Even though the business they have been in has change many times, I doubt whether anyone in the company would ever consider changing their name or acronym, immediately putting them into relative obscurity. The same is true about Nabisco (National Biscuit Company), RCA (Radio Corporation of

America), and many others. In fact, RCA uses the slogan “Technology Unleashed” in order to promote the company as an innovator, but also to connect to their past, successful heritage in which virtually all advertising included a graphic of the dog, Nipper. In the advertisements, Nipper is curiously looking into the amplifying horn of the gramophone, puzzled by the sound “Of His Master’s Voice,” Thomas Edison, its inventor, emanating from it (http://home.rca.com/en-us/PressReleaseLanding.html). ITEA has a slogan as well: “Teaching Excellence in Technology, Innovation, Design and Engineering” along with the acronym TIDE. As with RCA’s, it can change over time while preserving the fundamental identity of the organization and profession it serves.

My thoughts about our profession then changed from IBM blue to green. Recently, I visited the National Building Museum in Washington, DC. I was particularly amazed at the number of books about “going green” on display in the bookstore in the museum, ranging from “Green for Dummies” to complex books on green construction. As I have gotten older, I have become increasingly more interested in ecology and the environment – and green. Perhaps it is an attempt at reconciling some irresponsible behavior in my early years or maybe it is simply due to the maturity that comes with my advancing years. In any case, Earth Day this year took on a lot more seriousness than it had when I supervised my junior high students on a clean-up-the-environment field trip on the first Earth Day during my third year of teaching in 1970. Now my mindset is that we should not be “going green” but rather we should be “going back to green” – a place we should never have left in the first place. I felt particularly proud when the first “green building” on the Millersville University campus opened this year as the new home to the School of Education.

While in Washington, I read a newspaper article about the bottled water phenomenon that led me to an article written by Ramon Cruz, Senior Policy Analyst for Living Cities at the Environmental Defense Fund. We are paying $15 billion dollars a year for bottled water. More than one-fourth of this water is simply filtered tap water. In fact, the majority of tap water is just as pure as bottled water and sometimes even purer. Cruz cites the Pacific Institute analysis indicating that it required 17 million barrels of crude oil to produce the bottles for the water we consumed in 2006, enough oil to fuel over one million vehicles for a year. The manufacture of these bottles also produced 2.5 million tons of carbon dioxide and required three times the amount of water that eventually ended up in the bottles for sale to the consumer. Cruz also cites data that show that we recycle less than 20% of the 28 billion single-serving water bottles that we use each year. Then there are the non-renewable resources that are used to transport the bottled water from producer to consumer. I can only dream about what we could do with the $15 billion water money if it was transferred to our profession. I also think about the marketing implications to our field of the $1.59 per 20 ounce bottle of filtered water compared to the same price charged for 20 ounces of a name brand soda, along with the complexity of metering and mixing the seven ingredients of which the soda consists.

So what is our role in all this? First, in teaching our students about materials and processes we are uniquely poised to provide first hand experiences to them in how bottles are manufactured, including actual experiences with blow molding in at least some of our programs. There are highly engaging problem solving experiences we can provide to our students by challenging them to quantify the waste that is generated in our labs, how it can be reduced, recycled, and/or put to alternative use. As is so often true, we can provide learning experiences to our students, connecting knowledge and emotions in a real world setting, unlike any other program in the school. Second, technology education can be the leader within the school and within the community in developing a responsibility for environmental stewardship and changing attitudes. There is a considerable measure of logic in teaching students about the natural world (science) via the human-made world (technology), rather than the other way around.

Can "green" be our brand? Not likely, but clearly we have some significant responsibilities. Moreover, the unique challenges in which we can engage our students have some potential to get us in the minds of some influential people. On the other hand, everyone seems to be going green. In fact, going green has entered the forefront of business competition, with companies vying with each other to become the "greenest." Murawski (2008) mentions the increasing tendency of companies to engage in "greenwashing," making exaggerated claims about how green they are. No doubt this phenomenon will lead to government intervention to set standards on what green means, just as in the past with organic foods, gasoline mileage claims, and how much actual fruit juice must be in a product before it can be labeled as "fruit juice." As I remember the news commentator Paul Harvey say over and over, "You cannot have self governance without self discipline."

Should engineering be part of our brand? Already, what used to be the Technology Education Division of the Association for Career and Technical Education is now the Engineering and Technology Education Division (though the acronym uses a lower case *e:* "eTED"). The National Association of Industrial Technology is considering a name change and it is quite likely that it will contain the word engineering. So, just as companies are clamoring to become identified as being green, do we have a choice considering that our "colleague" organizations appear to be including engineering in their titles? On the other hand, have we changed names and brands over the years to create a more positive, marketable image to all those who we serve or have an influence on us? Or have we really engaged in our renaming and re-branding solely to serve ourselves, who are already in the profession?

There is some irony in this, at least at a personal level. In the 1980s, while I was a faculty member at Virginia Tech, we wished to change the titles of several of our courses in our technology teacher education program, using the word "technology." The faculty in engineering made it clear that technology was their domain, but compromised as long as "teaching" was part of the course titles. So, we ended up with courses such as "Teaching Manufacturing Technology" and

"Teaching Construction Technology." We would not even have thought about including "engineering" in any of our course titles or descriptions, certainly not in the name of our program.

In the hallways of the building in which our program is housed at Millersville University, there are display panels that contain the business cards of a number of our graduates who entered industry. Many of the titles on the cards include the word engineering, such as Product Design Engineer, Safety Engineer, and Manufacturing Engineer. Yet none of these graduates actually has a degree in engineering, but rather a degree in industrial technology. Though they may not be recognized as engineers in academia, they are certainly recognized as engineers in the real world since the companies that employ these individuals are the source of their titles. Is the word engineering losing its meaning since it is being used in such pervasive ways, similar to what happened to the word technology in the years since we changed our name in 1984? Will the word engineering soon be so commonplace that it has no significance? When I notice other organizations and entities that have no connection to us using the phrase technology education, I have to admit that it still causes my ire to climb. If we want to collaborate with engineering, do we need to obtain their blessing to use their name?

We do need to brand the horse we are riding. Recently I served on a proposal review panel for the National Science Foundation. All the proposals our panel reviewed were connected directly to technology education, yet few made reference to our field, our Standards, or our professional organization. Similarly, a colleague in our profession remarked to me about how few of the attendees at the recent American Society for Engineering Education knew about our field, adding that the organization appears to be "reinventing the wheel" that we have already made. Equally frustrating is how often a positive news article appears highlighting the wonderful things that one of our teachers is doing with students without making any connection whatsoever to technology education. Making this connection ought to be one element of a code of ethics for our profession.

When I think of the horse that we will ride into the future, I have to think (with tongue in cheek) of agriculture. While I was a faculty member at Montana State University some 30 years ago, I became increasingly impressed with agriculture education programs. At the time, there were 80 agriculture teachers in the State and 79 of them showed up for the annual summer conference in 1979. The no-show was very ill at the time. Agriculture educators have been able to connect their discipline tightly with their professional association and with their student organization. The Future Farmers of America (FFA) is their brand and is known and respected by all, from legislators to ordinary citizens. They were able to accomplish this with little effort in Montana since all of the teachers belonged to their professional association and were active in it. They had an effective "phone tree" to connect their profession to the state and federal government and collectively knew many government officials on a first name basis.

Starkweather (2008) concluded his report on the name change survey indicating that what is really important is not so much our name, but what we teach our students and what they will learn that will serve them well for the future. Having a good healthy horse that can get the job done, headed in the right direction, is more important than the saddle, the bridle, or the brand. Some of that bottled water money would help, though!

JEL

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Articles

Analogical Reasoning in the Engineering Design Process and Technology Education Applications

Jenny Daugherty and Nathan Mentzer

Introduction

This synthesis paper discusses the research exploring analogical reasoning, the role of analogies in the engineering design process, and educational applications for analogical reasoning. Researchers have discovered that analogical reasoning is often a fundamental cognitive tool in design problem solving. Regarding the possible role of analogical reasoning in the context of technology education; analogies may be a useful tool to develop student's design skills, teach abstract or complex concepts, and build students' analogical reasoning skills for general problem solving. The positive and negative educational implications of analogical reasoning being explored by researchers are also discussed.

With the development of the Standards for Technological Literacy: Content for the Study of Technology (ITEA, 2000) and a focus on the integration of engineering design, the profession has attempted to standardize, validate a need for technology education, and most importantly increase students' technological literacy. Technological literacy has been defined as the "ability to use, manage, assess, and understand technology" (ITEA, 2000, p. 9). The National Academy of Engineering and the National Research Council, in a joint report (2002), pointed to three interdependent dimensions of technological literacy: (a) knowledge, (b) ways of thinking and acting, and (c) capabilities. Engineering, with its emphasis on design, has been proposed to help bring about technological literacy and improve these cognitive skills (Dearing & Daugherty, 2004).

The emphasis on cognition within technology education has led to an increased focus on cognitive science research, which has sought to understand how people think and learn. These efforts have been used to better develop

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instructional strategies for applications such as teaching creative, real world problem solving. In this pursuit, researchers have examined how knowledge is constructed, stored, and utilized. Schema theory, for example, has been posited as an explanation of how knowledge is represented and then applied. According to this theory, knowledge is constructed and stored as mental models or schemata. Schemata are the active representations of knowledge and general belief structures that support understanding, reasoning, and prediction. Experiences and knowledge inform the creation of schemata and new knowledge leads to the revision of previously formed schemata. Schema must then be activated from memory to be used or revised (Ball, Ormerod, & Morely, 2004; Gentner, 2002). It is this active process that may be of particular interest to the field of technology education.

Understanding how engineering designers store and retrieve knowledge during the design process can be particularly beneficial to informing technology education. The retrieval of prior knowledge to solve engineering design problems is an important part of the design process. As evidenced in the following excerpt from a verbal protocol study by Ball, Ormerod, and Morely (2004), a subject recalled prior knowledge, stating, "I've designed outdoor terminals before, so, straight away, I'm thinking about how this relates to my knowledge of what I've done before…" (p. 7). This association between the current challenge (in this example: designing a rental car automated terminal) and past experiences (designing outdoor terminals) is fertile grounds for study. These links differentiate novice and expert designers and provide a tool for connecting previous experiences with new and unfamiliar challenges.

The storage and retrieval of knowledge within the problem solving process is of particular importance to informing the integration of engineering design content and processes into technology education. Design problem solving is an integral component of engineering and by learning from experts, educational practices can be better developed to teach novice students design skills. This integration has been spurred by many researchers within technology education. For example, Lewis (2005) argued that design is "the single most important content area set forth in the standards, because it is a concept that situates the subject more completely within the domain of engineering" (p. 37). Engineering design, however, is not yet fully understood and educators disagree how and at what level design should be taught. Technology education researchers and practitioners are faced with the challenge of how to teach engineering design authentically. An avenue of exploring expert design cognition with the intent of informing technology education teaching practices is to understand how designers store and retrieve knowledge within the associative, similarity-based reasoning system.

Analogical Reasoning

Two systems have been theorized to exist within a person's cognitive structure: (a) the symbolic system, and (b) the associative reasoning system, as shown in Figure 1. Schemata can be viewed as being stored and utilized in both of these cognitive systems. The symbolic or rule-based reasoning system is where abstract real world problems are reasoned about and solved through symbolic representations and rules. The associative, similarity-based reasoning system is where problems are reasoned about through associations or similarities with other known information. Although researchers disagree as to which system is dominant, this second system is significant because associative reasoning is viewed to be a fundamental part of expert design cognition (Akin, 2001; Goldschmidt, 2001).

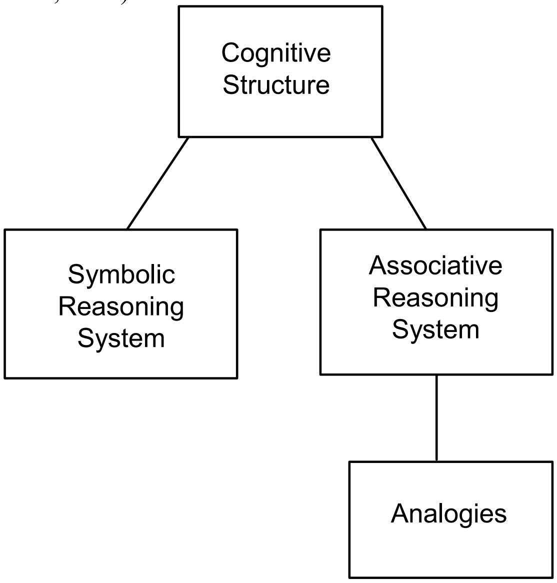

Figure 1. Graphic representation of the cognitive structure for reasoning through analogies.

Analogical reasoning is a function of the associative, similarity-based reasoning system, as shown in Figure 1. This type of reasoning is a method of activating stored schema based on the identification of connections, parallels, or similarities between, what are typically perceived as dissimilar items. Analogies serve as a type of scaffolding, where new information is anchored to existing schemata. Analogical reasoning is thus the use of schema analogues, or knowledge from previous experiences, to facilitate learning in a new situation (Ball, et al., 2004; Cross, 1994). Analogies enable an individual's symbolic ability or "the ability to pick out patterns, to identify recurrences of these patterns despite variation in the elements that compose them, to form concepts that abstract and reify these patterns, and to express these concepts in language" (Holoyoak, Gentner, and Kokinov, 2001, p. 2). Researchers have discovered that analogical reasoning is often a fundamental cognitive tool for design problem solving. Available resources already stored in the mind as schemata are recruited to fortify the search for problem-solving strategies through analogies (Goldschmidt, 2001).

Perhaps one of the most notable examples of design problem-solving through the use of analogies is the creation of Velcro®. According to the Velcro® Industries B.V.'s website, the inventor, George de Mestral's walk in the woods led to the hook and loop fastener component of the design. Mestral noticed the "natural hook-like shape" of the cockleburs attached to his dog's fur and his clothes. He recognized a parallel between the cockleburs attached to his fabric and the potential for a new design in mechanical fastening. To explore the potential of this new design, he analyzed a cocklebur under a microscope and then partnered with a fabric manufacturer to create a fabric system with characteristics similar to the cocklebur. He was able to envision the possibilities of creating a new design (Velcro) based on a naturally existing design (cocklebur) by drawing analogies between the two.

Structure Mapping and Learning

Structure mapping is a theory explaining analogical reasoning. Structure mapping theory posits that schema analogues can be viewed as being similar according to their relational structures or how they relate. In other words, an analogy is the identification of particular aspects of one item (referred to as the known or base domain), as being similar to certain aspects of another item (the unknown or target domain), as shown in Figure 2. The base domain and target domain are not similar on all accounts, but through structure mapping the relational structure of the base and target domains are found to be similar (Gentner & Gentner, 1983). Structure mappings allow for the construction of new schema based on inferences and predictions. The inferences undergo a transformation bringing the two items close enough together to allow mapping and transfer from the base to the target (Goldschmidt, 2001). Causality can then be inferred and causal mental models or schemata developed.

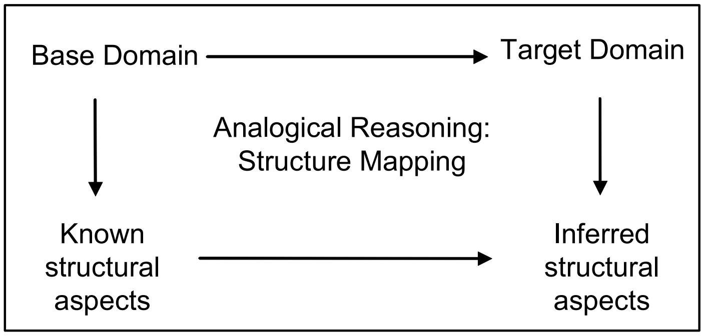

Figure 2. Graphic representation of the structure mapping process that explains analogical reasoning.

Similar to structure mapping, Holyoak and Thagard (1997) outlined the steps involved in learning through analogical reasoning, including; (a) the retrieval step, (b) the mapping step, (c) the inference step, and (d) the learning step. Moving from the target analog (base domain) to the source analog (target domain), analogies are accessed in the retrieval step when the learner is trying to reason about a new situation. During the mapping step, similarities or correspondences between the source and target are found. Inferences about the two domains are made during the inference step and then "a kind of abstraction of the commonalities shared by the source and target" (p. 35) is developed during the learning step.

Holyoak and Thagard further outlined a "multiconstraint theory" of analogical reasoning that explains how analogies are guided by three particular kinds of constraints: (a) similarity, (b) structure, and (c) purpose. The use of analogy is often guided by a similarity of concepts between the base and target domain. In addition, consistent structural parallels often exist between the roles in the base and target domains. Finally, analogical reasoning is typically guided by a purpose or a goal that the analogy is intended to achieve. According to Holyoak and Thagard, these constraints "function more like the various pressures that guide an architect engaged in creative design, with some forces in convergence, others in opposition, and their constant interplay pressing toward some satisfying compromise that is internally coherent" (p. 36).

Forms of Analogical Reasoning

Researchers have concluded that analogical reasoning can be categorized into two different forms. First, analogical reasoning can be used to understand the operation of a new device. Schema, or stored knowledge, of how a device operates is used to reason about how an analogous device might operate or understanding how to operate a device can be inferred from knowing how the larger system works (Kieras & Bovair, 1984). Second, analogical reasoning uses schema, or knowledge already stored, to reason about, infer, and/or predict information to solve a problem. In other words, analogue schemata are used to compare what is already stored as schemata, to a new domain of knowledge (Schumacher & Czerwinski, 1992).

These two basic forms of analogical reasoning (understanding the operation of a device and problem solving) are also commonly found in the technology education classroom, although they may not be made explicit to the students. For example, in teaching a lesson on automation, teachers may include an activity during which students learn to program a robotic arm. A typical robotic arm is anthropomorphic in structure, meaning that it is analogous to the human arm. Students easily relate their shoulder, elbow, wrist and fingers to the robot's arm and end effectors. This analogy aids the students in learning to program a pick and place operation using a new technology that might otherwise seem foreign and unfamiliar to them. The ability to use analogical reasoning about how the device will perform like a human's arm enables the students to develop schema about robotics.

In problem solving applications, students may be less aware of the use of analogical reasoning but can be made aware through instruction. The development of analogical reasoning can be an important tool in the development of students' engineering design knowledge. For example, in presenting students with the challenge of designing a tower for a shake table earthquake simulation, teachers can prompt students to draw on their knowledge of geometric shapes. Many students have learned that triangulation leads to structural stability. During the design and building of this activity, students who consider the analogy between their understanding of triangulation and stability in the design of their tower may be able to reason through their design more easily. An optimization process emerges as students balance the need to conserve building materials in order to meet the goal of a tall structure, with the need for stability during the shake.

Metaphors, Literal Similarities, and Types of Analogies

An important distinction should be made between metaphors, literal similarities, and types of analogies. According to Gentner and Jeziorski (1993), metaphor can be viewed as a broad category encompassing analogies. However, Miller (1993) argued that in a broad way, "any expression of similarity or resemblance can be called an analogy" (p. 378). A way to distinguish between the two is to categorize metaphors as items compared from the same category and analogies as items compared from different categories (Saha, 1988). The "grounds for a metaphor, therefore, can be formulated as relations of similitude that can be expressed as comparison statements" (Miller, 1993, p. 398). An analogy is perhaps a more creative comparison of less similar relations. An "analogy is a way of aligning and focusing on relational commonalities independently of the objects in which those relations are embedded" (Gentner & Jeziorski, 1993, p. 449).

Gentner and Gentner (1983) clarified the distinction between literal similarities and analogies by referring to how the items are structured as schema. Items are literally similar when the particular characteristics of the items are the same. Items are analogous when the relational structures are similar, but the particular characteristics of each item are not the same. Two different types of analogies can be distinguished as shown in Figure 3, surface feature analogies and generative analogies. Goldschmidt (2001) pointed out that analogies can have either structural or surface feature commonalities that are carried over to new items or situations. Items that are analogous based on their surface features, however, may not be analogous structurally or conceptually. For example, language or analogical terms can be borrowed from one domain as a convenient way of talking about another domain.

Generative analogies are the type of analogies that provide the ability to make inferences from the base domain to the target domain. These inferences can be made because the analogous relationship between the base and target domain is based on more than the surface features of each. The structure of each domain is similar enough conceptually to generate inferences from what is

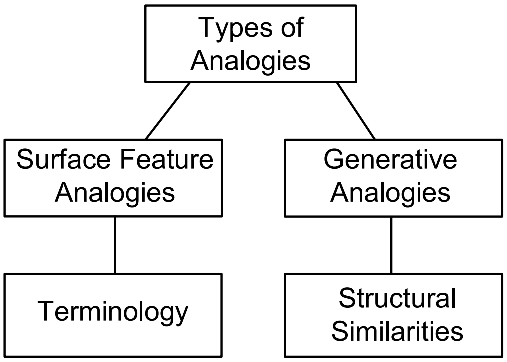

Figure 3. Types of analogies.

known about the base domain. Not only inferences, but also predictions can be made based on analogies. In other words, analogies allow a person to go beyond the familiar and reason about the unfamiliar (Collins & Gentner, 1987). Goldschmidt (2001) pointed out that inferences and predictions with generative analogies can be made because they are often not just identified but visualized. Individuals are able to imagine or "run" actions in their minds, such as causality, based on what is known about the base domain.

Classroom Examples

Literal similarities, metaphors, and surface feature and generative analogies may all be identified in the classroom. For example, commonly found in technology education classroom are various tools such as multimeters or handheld GPS units. School districts often purchase these tools over a span of a few years and thus classrooms may have multiple units of different models or brands. A teacher will typically provide a demonstration on one unit and expect the students to be able to see literal similarities and realize that each unit will have the same features while the physical appearance may vary drastically.

Metaphors are often used during instruction. Metaphors can serve as "linguistic tools for overcoming certain cognitive limitations" (Sticht, 1993, p. 622) by extending students' active memory through language. A great example of using metaphors in technology education is in the teaching of machining patterns during a lesson on CNC milling. Students are typically more familiar with the use of a lawn mower than they care to be and this provides for a solid knowledge base from which to understand machining patterns. A facing, pocketing, or contouring operation can be compared to cutting grass with the lawn mower. Such concepts as depth of cut, finish passes, and method of cut such as: zig-zag, one way, and spiral lend themselves to comparison with lawn mowing activities. Students clearly understand that tall grass will required multiple depth cuts and/or slower traveling speeds, just as a rotating tool would break if presented with an excessive depth of cut and/or traverse speed.

Surface feature analogies rely primarily on terminology. During a lesson on laser technology, the light from a laser is analogous to a beam and hits a point on the wall or target. While a laser beam and a beam used in the construction industry are two very different concepts, they share some common surface features: they are both straight, with a relatively small cross-sectional area. While the laser beam illuminates what is described as a point, the target has a cross-sectional area that may be more appropriately termed a small circle (assuming the aperture is circular). A point is a theoretical concept, but in this case, it creates an analogy differentiating the laser beam from typical incandescent or florescent lighting that floods the room.

The use of generative analogies in the classroom is exemplified by Gentner (1981). A student highlighted his or her understanding of electricity by employing a generative analogy, stating:

> If you increase resistance in the circuit, the current slows down. Now that's like a high—cars on a highway where you—if you notice as you close down a lane, you have cars moving along. Okay, as you go down into the thing, the cars move slower through that narrow point. (p. 1)

The student compared the flowing electricity to their knowledge of automobile traffic on a highway. Their ability to visualize and "run" a simulation of manipulating a variable in this system and predicting its effects on the system's behavior is demonstrated. If cars slow for a restriction, then current must slow when resistance is encountered. As discussed, literal similarities, metaphors, and analogies are often used tools in the teaching of technology and can be furthered enhanced to better prepare students' problem solving skills.

In their engineering text, Dym and Little (2004) promoted the use of similarities, metaphors, and analogies to encourage creative, divergent thinking in students. In particular they argued that analogies have the potential to be "very powerful tools in engineering design" (p. 103). For example, they compared the designs of scaffolding and angioplasty to indicate the ability of designers to stretch their knowledge to be able to solve complex design problems. An angioplasty stent's intent and function is similar to scaffolding erected to support walls in mines as they are being built. A stent supports the walls of the artery as surgeons operate. This example makes clear to students that inspiration can be found in other designs whether they are directly similar or only similar in terms of form or function.

Expertise, Design, and Analogical Reasoning

Expert analogical reasoning has been studied to understand how to better develop this cognitive tool in novices. Dreyfus and Dreyfus (1986) stated that the ability to analogically reason is an important component in the development of expertise. They outlined five stages in the progression from novice to expert. This progression is characterized by performance based on the analytic, detached behavior of the novice, to the involved, experience-based behavior of an expert. One of the components Dreyfus and Dreyfus saw as a distinguishing mark of proficiency in performance was the ability to recognize new situations as similar to remembered situations (i.e., the ability to use analogies).

Other researchers have differentiated between the type of analogical reasoning used by experts and novices. Ball, et al. (2004), for example, concluded that expert engineering designers use more schema-driven analogizing while novice engineering designers use more case-driven analogizing. Schema-driven analogizing is the application of abstract knowledge to familiar problem types, affording a design solution seemingly effortlessly. Ball, et al. concluded that experts develop numerous design problem schemata because they are exposed to and learn from many domain-specific problems. Experts develop a conceptual understanding of the underlying nature of domain-specific problems, which then enables them to recognize problem types. Experts not only engage in schema-driven analogizing, but also spontaneous analogizing. When an expert encounters a problem, an appropriate schema that is analogous to the problem type is automatically accessed. This schema usually indicates a straight-forward solution method based upon previous application of the solution to the analogous problem.

Novices, however, have not had the opportunity to develop a repertoire of analogous problem type schemata. They rely heavily on case-driven analogizing when solving design problems. Novices apply specific solution elements from prior design problems to current problems. Novices do not recognize problem types as do experts; instead they analogize according to the specific components of the problem-solution schema. Interestingly, Ball, et al. found that experts and novices alike use this method when experts encounter non-routine engineering design problems. When experts face a problem that cannot be spontaneously mapped to an analogous problem type and cue appropriate solution methods, they focus on developing surface level analogies between the target problem and similarly encountered cases.

Case-based reasoning (CBR) is a methodology that was originally developed in the realm of computer cognition, but as Kolodner (1997) discussed, it has been extended to explore human cognition as well. CBR has two central components; (a) the use of analogies to solve real-word problems, and (b) the use of computational modeling to derive hypothesis about cognition. Analogies in CBR typically reflect personally experienced situations called cases and include “a sought-after goal, a method for achieving the goal or solution to the problem and the results (outcome) of carrying out that method (solution), all of this described specifically” (p. 59). The intention is to provide cases so as to enable the development and use of analogical inferences to help solve real-world problems.

The representation of the problem has been found to be an important component in analogical reasoning in design problems. Akin (2001), for example, found that analogical reasoning is based on how directly the given problem corresponds to the problem solver’s schemata. If the problem is ill-defined, the problem solver must continually re-structure the problem in order to search for an appropriate solution. These frequent shifts of problem representation can affect the use of analogical reasoning. Because experts seem to rely on problem types to invoke analogous problem schemata, an ill-defined problem, which does not fit into a recognized problem type, requires frequent restructuring or the use of other search strategies besides analogical reasoning in order to develop an adequate solution.

Analogies and Creativity

Another important component of analogical reasoning in design problems is creativity. As Perkins (1997) articulated, analogy is "the creature that carries people's cognitive capacities across the desert of unworkable possibilities from the familiar to true innovations" (p. 524). Specifically, analogies can play an important role in conceptual change, which is a crucial aspect of creativity. Four analogical processes can be used to spur conceptual change: (a) highlighting, (b) projection of candidate inferences, (c) re-representation, and (d) restructuring (Gentner, et al., 1997). Analogies focus attention on specific aspects of the base and target domains, highlighting relevant information. By projecting inferences, analogies aid in the development of knowledge within the target domain. Re-representing either or both the base or target domain to improve the analogy can further establish conceptual change. Finally, analogies can spur the restructuring of elements of the target domain to form a new explanation.

Educational Applications

Researchers have examined the issues involved with the use of analogies in instructional practices within design. Although analogical terminology is already an often used instructional technique, as Gentner and Jeziorski (1993) pointed out, analogical reasoning is rarely formally taught to students. Typically, language is borrowed from one domain to talk about another usually more complex domain. Instructors seem to believe that students can learn concepts and operations in a new domain by connecting to similarities from a previously learned domain. Instructors teaching electricity, for example, often rely on analogies such as comparing similar features of water to electricity (Gentner & Gentner, 1983).

However, as pointed out earlier, surface commonalities do not necessarily mean that the base and target domains are analogous structurally. Superficially similar problems may not have underlying similarities to where appropriate solutions can be inferred (Ball, et al., 2004; Goldschmidt, 2001). Kempton (1986), for example, found that many individuals' analogies for thermostats were not structurally similar to how thermostats actually operate. Many analogized that their thermostat system operated like a valve. Although the valve analogy provided for correct functionality of the thermostat, the complete understanding of how thermostats operate would have required a total replacement of the analogue schema. Thus the reliance on analogical reasoning can be problematic for instructors. For example, schemata developed from experience can be resistant to change through instruction (Getner, 2002). Even when presented with conflicting information, individuals are likely to hold onto their existing schema. This persistence has been referred to as a cultural boundary. Isolated elements or terms may be incorporated into the existing schema, but the underlying schema will remain unchanged (Kempton, 1986).

Halasz and Moran (1982) warned against using analogies to teach new learners computer systems because of these problems. They argued that analogies may actually hinder, not help, the development of a good understanding of the target domain because "analogical reasoning requires considerable work to sort out the relevant mappings and allowable inferences" (p. 385). Instead, they recommend using conceptual models, which can be shaped without the "baggage" of analogies. Conceptual models represent the underlying conceptual structures within a specific context, providing a sound basis for reasoning about the system. Although analogies provide a link to a learner's prior knowledge, conceptual models increase the learner's reasoning abilities because complexities of a system are reflected more so in a conceptual model than in an analogical model.

Other researchers, however, have argued that analogical reasoning can be a powerful instructional strategy because students already rely on analogical thinking to comprehend the world and solve problems. Goldschmidt (2001), for example, declared that people can be trained to maximize the processing resources with which they are endowed. As Holyoak and Thagard (1997) pointed out, young children "before they enter school, without any specialized tutoring from their parents or elders, develop a capacity for analogical thinking" (p. 35). Based on this belief, students can then be taught to improve their analogical reasoning skills. Instructors may also utilize analogies to better teach abstract information. Analogies can be used to increase far learning transfer by bridging knowledge from familiar domains to abstract, unfamiliar domains. Bridging analogies is a type of scaffolding where new information is anchored to existing schema. By progressing in small steps, using analogies along the way, the learner gradually moves to another way of conceptualizing the concept or domain, and ultimately forms a new schema or revises an existing schema (Gentner, 2002).

Analogical reasoning has been studied, however minimally (Goldschmidt, 2001), in the hopes of informing the teaching of design problem solving. Thagard (1988) offered a series of questions that the problem solver can ask and answer to aid in analogical reasoning. Thagard argued that the identification and retrieval of an analogy "must be followed by an attempt to exploit the analogy to produce the desired result of analogical reasoning" (p. 108) within the context of problem solving. The questions Thagard provided include:

1. What are the general aspects of the starting conditions and the goals?
2. What are the relationships among the objects in the starting conditions and the goals?
3. What past problems does this problem look similar to?
4. During problem solving, what constraints are violated by failed attempts? Are those similar to constraints violated in previous problems? (p. 119)

Analogical reasoning has also been formalized into a creative design method called synectics as discussed by Cross (1994). Synectics is a group design method. Groups attempt to build, combine, and develop ideas toward a creative solution by using analogies to make the strange familiar. Synectics is similar to brainstorming; however, the group works toward a particular solution rather than generating a large number of ideas. As the group uses more and more analogies, a conceptualization of the problem is developed that guides the development of a solution. The group is encouraged to use particular types of analogies to help develop unusual, creative ideas. The following is a description of the different types of analogies used in synectics:

> *Direct analogies*: are found by seeking a biological solution to a similar problem. For example, plant burs were used as analogy to design Velcro fastening.
>
> *Personal analogies:* are used by designers when they imagine what it would be like to use themselves as the system or component that is being designed. For example, designers might ask questions like how would I operate if I were a washing machine?
>
> *Symbolic analogies:* are poetic metaphors and similes that are used to relate aspects of one thing with aspects of another. For example, words like "head" and "claw" can be used to describe aspects of a hammer.
>
> *Fantasy analogies:* are impossible wishes for things to be achieved in some magical way. Designers envision the ultimate goal, for example, making bumps in the road disappear beneath a car's wheels (Cross, 1994).

Analogies and Technology Education

Analogies may be a useful tool to not only develop design skills, but teach abstract or complex concepts and build analogical reasoning skills, within a technology education setting. Opportunities to model and use analogical reasoning are abundant within technology education. A broader approach to using analogical reasoning in a technology education setting would be to first establish the base domain. For example, by first building a schema around a systems approach (input→ process → output; and feedback), analogies can be used to understand a multitude of technical processes. The systems approach focuses on the structure of the system or how the components are connected to each other, the function of the components within the system, and the behavior of those components. By understanding the systems approach, students can better understand the causal interactions that occur between components or devices. An excellent example in technology education is the explanation of inter-modal transportation. There are many components to inter-modal transportation; however, with an understanding of systems thinking, students can more easily map the inputs (cargo), the processes (containerization), and the outputs (shipping, globalization, economic growth, etc.).

Conclusion

The use of analogies as proposed is subject to empirical evidence to support their effectiveness. Perhaps the most essential component to validate the use of analogies as an instructional strategy is to first understand how to assess student's base domain knowledge. Effective analogical reasoning requires that the base domain knowledge is correct. As pointed out by Lewis (1999), there is a need in technology education to examine questions pertaining to student's conceptions and misconceptions of technological phenomenon in order to better inform teaching practices and improve learning. Lewis proposed parallel studies to those done in science examining student conceptions of such things as energy and thermodynamics, be completed in technology education.

Other research needs to be completed to examine the role of analogical reasoning in design and its implications for technology education. For example, studies that examine synectics in the classroom need to be completed. Synectics has been formalized as an expert design method, but how will novice students engage in this type of approach to design? More research also needs to be done to explore the effectiveness of using analogical reasoning in design. Is this an approach that should be taught to novices or one that develops naturally through experience? More thorough understanding needs to be uncovered about the "baggage" described by Halasz and Moran (1982). Should analogizing not only be avoided, but actually be dissuaded as an approach to problem solving and design? Analogical reasoning is just one of many important elements in design cognition that, with more empirical research, can inform and improve technology education practices.

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Engagement and Achievements: A Case Study of Design-Based Learning in a Science Context

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Introduction

A major goal of science education reform is to produce curricula that improve the learning of all students. In this study we explore the use of design-based learning to achieve this end.

Unlike the great majority of industrialized nations in the world, K-12 education in the U.S. places very little emphasis on design and technology. Design and technology education is not a required subject in high school in most schools. Even in the middle school level, it is typically an elective subject and is not offered in all schools (Dyer, Reed & Berry, 2006).

On the other hand, U.S. schools of engineering are placing more emphasis on teamwork, design process skills, and hands-on construction. For this and other reasons, various state science standards are beginning to push for a more serious role for design and technology in the K-12 curriculum. Yet current science K-12 curricula have not yet caught up, and the treatment of design and technology is typically weak. Most science curricula lack engineering background beyond information technology (IT) subjects (De Vries, 1997).

There is a new development, under the general name of Design-Based Learning (DBL), that is attempting to address this problem (Kolodner, et al., 1998; Rivet & Krajcik, 2004). The design process is rich and multifaceted and might be capable of producing new knowledge in a way that is analogous to the scientific inquiry process. What, then, is DBL and how does it relate to scientific inquiry?

> Inquiry is a multifaceted activity that involves making observations; posing questions; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. (National Research Council, 1996, p. 23).

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Despite this grandiose definition of inquiry, most of the science curricula that are implemented in US schools use scripted-inquiry rather than authentic inquiry. In scripted inquiry, the teachers set the goal, ask the questions, provide the materials, provide the procedures, and discuss with the students the “correct” results and the “correct” conclusion (Bonnstetter, 1998).

By contrast, DBL provides a reason for learning the science content by engaging the student in design and using a natural and meaningful venue for learning both science and design skills. The collaborative nature of design provides opportunities for teamwork (Kolodner, 2002).

DBL enables students to experience the construction of cognitive concepts as a result of designing and making individual, inventive, and creative projects, to initiate the learning process in accordance to their own preference, learning styles, and various skills. It also assists the teacher in creating a community of designers who are partners in teamwork (Barak & Maymon, 1998; Doppelt, 2005; Resnick & Ocko, 1991). In this way, students combine “hands-on” activities with what Papert (1980) has termed “heads-in” activities. When students create projects, they experience meaningful study that enables the exercising of sophisticated ideas that arise from their own projects (Doppelt & Barak, 2002).

In addition to providing students with a rich understanding of design and technology, DBL can have several other advantages. First, since good design involves meeting current and real needs, students are motivated to learn because of the more obvious application of their knowledge to real life situations (Doppelt, 2003; Hill & Smith, 1998).

Second, DBL is an active process and has all of the advantages of active learning. Active learning is an educational approach that puts the students at the center of the learning process and recognizes the variation among different learning styles (Dewey, 1916; Gardner, 1993; Kolb, 1985; Perkins, 1992; Sternberg, 1998). Active learning changes the teacher’s role from that of lecturer to the roles of tutor, guide, and partner in the learning process (Prince, 2004). The knowledge gained through active learning is constructive knowledge and is not the type of knowledge that results from memorizing and doing exercises or homework from books (Gardner, 1991).

Third, DBL is typically a team activity, and thus has the advantages of collaborative learning. Students who have learned through cooperative methods gain success in academic and non-academic achievements (Lazarowitz, Hertz-Lazarowitz & Baird, 1994, Verner & Hershko, 2003). Working in teams generates a greater number and variety of ideas than by working in isolation (Denton 1994). A learning environment that allows teamwork can help students develop their interpersonal communication skills, presentation skills, and problem solving skills (Butcher, Stefanai & Tariq, 1995; Doppelt, 2004; 2006).

At the same time, DBL may present new difficulties for student learning, especially in the low-performing situations in K-12 science education. Many US teachers have weak preparation in science, but it is even weaker in design (Ritz

& Reed, 2005). DBL may motivate students, but the open-ended nature of design may leave low-achievers behind. This is certainly the case when teachers attempt large design projects only with gifted and talented classes. The task of navigating science content, the design process, and teamwork skills may be too much of a cognitive load for low-achieving students.

The design process is parallel to solving problems and has a general structure which typically includes stages such as: defining the problem and identifying the need, collecting information, introducing alternative solutions, choosing the optimal solution, designing and constructing a prototype, and evaluation. However, the 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 (McCormick & Murphy, 1994). In order to avoid teaching a general design process that can become rigid, it has been argued it is essential that teachers assist pupils in integrating knowledge from science and other disciplines into their design thinking (de Vries, 1996). It is not essential or even advisable that pupils construct their ideas, solutions and products following a specific set of design process steps. What is essential is to teach them to document properly and to learn to reflect on their creation (Sanders, 2000; Doppelt, 2007).

This paper explores these issues in a case study of an urban, public, middle school in a slightly below-moderate income neighborhood. We examined two middle school science classes taught by a teacher who switched for the first time from a standard, scripted inquiry approach to a design-based learning approach. The researchers were particularly interested in two questions. First, will students previously labeled high and low-achievers become equally engaged by DBL? Second, will the traditional gaps in science achievement associated with race/ethnicity, gender, and socio-economic status be increased or reduced? Work outside the U.S. suggests positive results are possible (Barak & Doppelt, 1999, 2000; Barak, Eisenberg, & Harel, 1995; Barlex, 1994; Prince, 2004). But the lack of history with DBL in the US may produce different results, as may the socio-cognitive realities of U.S. urban education.

Methods

Prior District Context

In this research, we initiated an in-depth case study of enhancing science education through design-based learning. Prior to this study, the researchers (the three first authors) identified a gap between the state and local science standards and the learning environment that was being used in this district. The gap between the standards and the implementation of the existing learning environment was particularly lacking in the design process. The specific standards that were being neglected were: (1) Know and use the technological design process to solve a problem, and (2) Explain the parts of a simple system and their relationship to each other.

The researchers initiated several interactions with personnel in the district instructional division. Through discussions with the coordinator and the district instructional support tutors, the group agreed that a design-based model might benefit the instruction that was occurring in eighth grade science classes, particularly in the half-year module involving the teaching of concepts around electricity and electronics. The prior instruction that was used in this electronics module emphasized a scripted-inquiry approach (i.e., students were told exactly how to conduct each inquiry activity via step-by-step procedures and worksheets).

The Design Curriculum

In order to include technological design and systems thinking, we developed a new learning module, a process of teacher training, and a plan for implementation in the regular science curriculum. The resulting module, Electrical Alarm System: Design, Construction, and Reflection (Doppelt, Mehalik & Schunn, 2004), was organized according to a variation of a creative thinking framework (De Bono, 1986) applied to design. The framework's components are: **P**urpose, **I**nput, **S**olutions, **C**hoice, **O**perations, and **E**valuation (**PISCOE**).

The module included modes of design thinking such as needs, requirements, generating solutions, and making decisions, thus following a process similar to the way that engineers design new systems. No concepts were explained declaratively until there was a need among students to do so, and only after a period in which students themselves attempted to investigate/discover the concept. Students and teachers followed a systems design approach (Gibson 1968; Blanchard & Fabrycky 1998) throughout the course of the 4 –5 week implementation.

The students learn about: (1) Alarm systems - where they can be found, reasons such systems exist, how they work, and how to build such a system; (2) Technological systems and subsystems, along with the purposes of such systems; (3) Constructing an alarm system in order to learn how electronic components can applied in developing such a system; (4) Brainstorming, communicating, documenting, working in teams, and designing technological systems for solving problems; 5) Developing criteria for assessing the design process; 6) Evaluating alternative designs as problem solutions; and 7) Reflecting on the design process.

Participants

In this study, we closely examined the implementation of the module with thirty-eight students in two science classes. Each class meets for one hour, five days per week. The students were in the eighth grade (thirteen to fourteen years old) in a middle public school in an urban district. The teacher has a masters' degree and thirty years of experience in teaching science at the elementary and middle school levels.

One class was considered by the school to be a low-level class. The other class was considered to be a high-level class (see Table 1). The school assigns students to the classrooms based on previous students' overall achievements in a variety of subjects (e.g., science, math, English, etc.) in the prior school year.

Table 1
Ethnicity, gender, and socio-economical status distribution of students among the two classes.

	Low Achievers Class (*n* = 22)	**High Achievers Class (*n* = 16)**
% Minority	41	25
% Male	55	38
% Low SES	50	50

Based on many years of prior experience with such students in general and two prior grade reporting periods of experience with these particular students, the instructor was expecting the lower achieving class to perform less well in the science class.

The number of students receiving free or reduced price lunches was used to determine the Socio-Economic Status (SES) reported in Table 1. A number of variables are used to determine eligibility for these lunches and include income, welfare payments, family size, and number of children in school. This variable as an indicator of SES is typically a strong predictor of student performance in science in the US.

Data Collection and Analysis

To develop an in-depth understanding of student engagement and achievement in this setting, we analyzed three sources of data:

1. Knowledge Test (KT)

The researchers specifically created a seven-question multiple-choice knowledge test that was designed around core concepts in electricity, such as resistance, current, voltage, and series and parallel circuits. This was done in order to ensure that all the core concepts that have been previously taught by the district would be included in the knowledge test (Mehalik, Doppelt, & Schunn, 2008). Students were given a pre-test and a posttest to measure changes in their knowledge of electricity concepts. There were two versions, randomly assigned to each student. The pre-test was administrated before any instruction in electricity began. The post-test was administrated immediately after the last day of the five-week module.

2. Oral Presentation Assessment

After the teams had completed each section of the learning module, transparencies were used to present their progress to the class. At the final stage of the learning module each team was required to present the entire design and build process. A teacher assessment and peer-assessment were done for each of these team presentations. Both teachers and peers used the same four criteria to assess each team presentation: knowledge of information, explanation of each item, use of the alarm system model, and use of transparencies. The teacher and each student scored the performance of each of team presentations on a scale of 5 (advanced) to 1 (unsatisfactory).

3. Analysis of student portfolios

All thirty-eight student portfolios and team documentation consisting of twelve sets of presentation transparencies were collected. Data from two teams were randomly selected for detailed analysis from those teams that performed at average levels on the knowledge tests. In addition, the researchers performed observations of 64% of the class activities within the module. Two researchers observed the same class periods and kept simultaneous but independent observation logs of students. These data provided additional support to the other observations.

Results and Interpretations

The results are divided as follows. In the first section the researchers analyze and compare high and low level students based on the results from the pre- and post- knowledge tests. In the second section, the overall performance of students relative to gender, ethnicity, and SES is reported. In the third section, the researchers describe the team documentation portfolios of two teams, one drawn from the high level students and one from the low level students. This was done in order to provide a detailed qualitative perspective of their performance in the DBL environment.

Achievement

Figure 1 presents the results from the knowledge tests. The standard error bars show a significant difference ($p < .05$) when they are not overlapping (Cumming & Finch, 2005). These findings indicate that DBL may be promising in reducing traditional achievement gaps, especially between the minority and the non-minority students and/or between the lower and higher SES.

Figure 2 shows a comparison of knowledge test scores between the low-achievers and high-achievers. The high-achievers gained significantly in the post-test ($t = 2.24$, $p < 0.05$) while the low-achievers improved but their improvement was not significant ($t = 1.49$, $p = 0.14$). Related research found that reading performance explains in part the lower performance on pen and paper tests such as this (Silk, Schunn & Strand Cary, 2007). Because the students were broadly grouped into classes by prior academic performance, reading performance differences may explain this result.

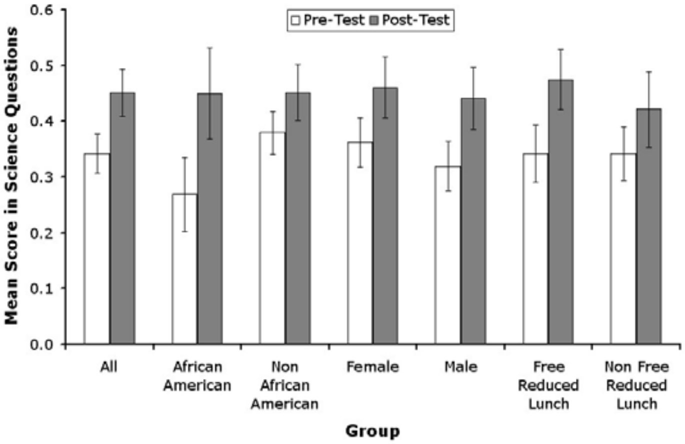

Figure 1. Mean Knowledge Test performance (with Standard Error bars) broken down by gender, race/ethnicity, and SES

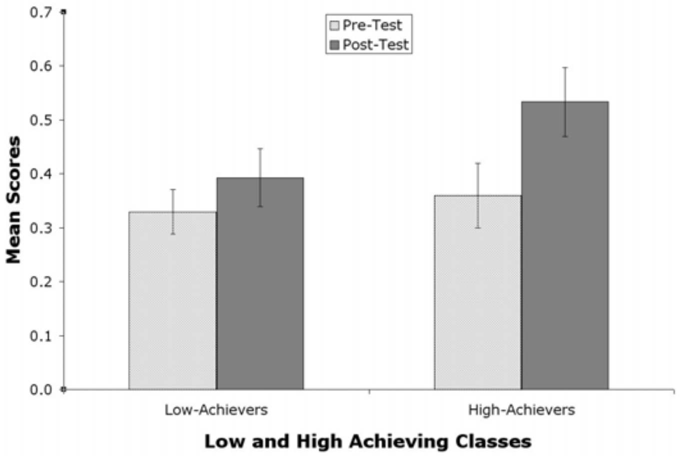

Figure 2. Knowledge test performance (Mean scores with SE bars) – Low/high achievers

Figures 3a and 3b present the results from the peer and teacher assessment that was done in both classes. The low-achievers scored their peer's presentations significantly higher than did the high-achievers. Of course, it may simply be that the students in the low-achieving class were more lenient. However, the teacher's ratings largely mirrored the student ratings. Furthermore, comparing peer-assessment and the teacher's assessment with the researchers' observation notes, the low-achievers generally presented their alarm solutions with a higher level of performance. The only exception to these findings was the criterion "Use of alarm system model." According to the teacher's assessment, the high-achievers used the alarm system model slightly better than did the low-achievers. Thus, we have some evidence that the knowledge test did not present a fully accurate picture of the differences across the classrooms.

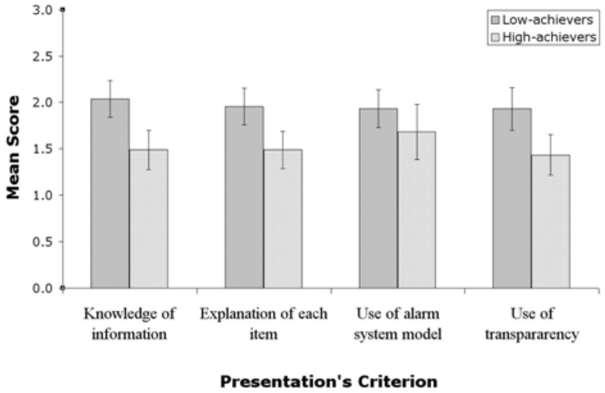

Figure 3a. Peer Presentation Assessment (Mean scores with SE bars)

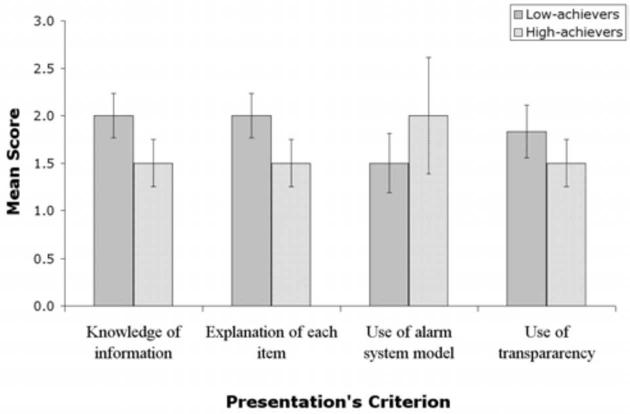

Figure 3b. Teacher Presentation Assessment (Mean scores with SE bars)

Portfolio Assessment

The portfolios were assessed to delve deeper into how the students went about designing their solutions. One portfolio was selected to represent the high-achievers and a second was chosen to represent the low achievers. These two portfolios will be available online shortly after this issue is published at http://scholar.lib.vt.edu/ejournals/JTE/. The representative portfolios were selected based on the knowledge test and on the observation logs of the researchers. The detailed portfolios show how each type of student engaged approached the different phases of the design process from beginning to end.

The "*Oh-snap, someone stole my stuff alarm*" ("Oh-snap") is the name of the alarm system that a team of four boys chose to work on. The second example tells the story of a team of three girls who chose to work on "*Medicine alarm"* ("Medicine"). According to the pre-test scores the students from the "Medicine" team were slightly above the mean scores of their high-achieving group. The students from the "Oh-snap" team were slightly below the mean score of their low-achieving group. The process steps in which the students were engaged included:

Step 1: Generate and document needs.

An important stage of design thinking is to realize that designs must meet needs. This introductory step engaged students in generating several different needs in their environment (see Figure 4, available online). For each need, they generated different possible solutions. A central idea in this activity was to engage all students in the activity. In most cases all the students in a team contributed ideas to the team transparencies. Another contribution was to add alternative solutions to ideas that other members in the team had raised.

Step 2: Develop a requirements list for the designed artifact

An important step in designing a new solution is to define requirements in order that the solution will meet the need (see Figure 5, available online).

Step 3: Develop an Input/Output model for the designed artifact

In this step, the teams described their alarm problem using a systems model, and then specified the information, energy, and material inputs, along with the positive and negative outcomes (see Figure 6, available online). Creating a systems model engages students in considering the impact of their alarm system on the environment. In addition, understanding input-output relations may assist students in understanding the structure of the system from a broader perspective.

Step 4: Develop function list for the designed artifact

In this step, students defined the functions that the system needed to have in order to meet the specified requirements (see Figure 7, available online).

Step 5: Develop system/subsystem analysis for the designed artifact

From the functions list, the teams created a visual sub-systems model (see Figure 8, available online).

Step 6: Develop decision matrix for selection among alternative design solutions

In this stage, the teams chose a solution for further design refinement and construction (see Figure 9, available online). The list of requirements previously generated served as criteria in the selection of the optimal solution.

Step 7: Continuous documentation through sketching.

Sketches showed how they thought about their design, beyond the electronics elements (see Figures 10-12, available online).

Step 8: Continuous documentation through reflection tables.

Reflection tables are an important stage during the design process. Requiring students to reflect about what they are doing as the design developed assisted them in connecting the work that they had done to this point and effectively plan the next stage (see Figures 13 & 14, available online). The reflection tables also revealed how scientific concepts were applied in the design process. For example, most of the groups in this class (and in other classes) used a parallel circuit before trying a series circuit. They called it “full connection.” Using reflection, they succeeded in creating sophisticated alarms circuits.

Teachers in the professional development workshop for the project had difficulty in understanding how these circuits worked and sought help from the researchers and their peers in how to teach their students. They learned that much of the difficulty of understanding the circuits came from the fact that series circuits were typically taught before parallel circuits in science class. Reversing the order seemed to increase understanding.

Both selected portfolio teams thought of an electrical resistor as an instrument to fine-tune the sound of the buzzer. The researchers noted that most science teachers with whom they have worked in professional development workshops did not understand this. This led the researchers to conclude that the students had developed a rather sophisticated understanding of the role of a resistor in a circuit – one that most adults do not have.

Step 9: Final process reflection

In this stage, teams were required to reflect on the entire design process. Using their previous documents and circuits, they reviewed their own creation process again and prepared themselves to present their complete design process in front of the class. The final team reflection on the design process was organized according to the six non-linear stages of PISCOE (see Figure 15, available online).

Table 2 compares the primary differences in documentation for each step of the design process between the two teams. These data provide an overall perspective of the portfolios of the low achieving class team to the high achieving class team.

Table 2
Documentation comparison between teams for each of the eight steps of the design process

Design stage	Actual steps	**Oh-snap** (low achieving group)	**Medicine** (high achieving group)
Purpose	Step 1: Needs	All the ideas were original	Two ideas were the same
	Step 2: Requirements	Eleven requirements, the only group that thought of a testing sub-system	Ten requirements
	Step 3: System Model	Identified clearly the negative outcome	Did not identify clearly the negative outcome
Input	Step 4: Functions	Five functions	Four functions Two functions were very general and not unique to the specific alarm that they designed.
	Step 5: Sub-Systems	Identified sub-systems	Identified very well the nature of each of their sub-systems
Choose Solution	Step 6: Matrix	Evaluate their alternatives based on the “Must have requirements”	Evaluate their alternatives based on all requirements
Operations	Step 7: Sketching	Few sketching mostly of circuits	Lot of sketching dealing with variety of aspects of their “medicine” alarm
	Step 8: Reflection	Seven different reflection tables	Only two tables
Evaluation	Step 9: Final reflection	Had some thing to reflect upon in each stage	Almost two columns with out any reflection

In comparing the two portfolios, the following observations can be made:

- The low-achiever team showed more generative thinking for five steps (steps 1, 2, 4, 8, 9)
- The low-achiever team showed better ideas for four steps (steps 2, 3, 4, 6)
- The high-achiever team showed more generative thinking for one step (step 7)
- The high-achiever team showed better ideas for one step (step 5)

In other words, there is a general pattern (with the exception of sketch generation) in that the low group shows more generative thinking overall and better ideas in the portfolio despite lower overall scores on the pen and paper knowledge test. The minor exception might be explained by our observation that the “Medicine alarm” team liked very much to draw and sketch along the whole design process, while the low-achiever team seemed significantly less interested in doing so. Both groups were so captivated by their idea that during the presentation session they often needed to be told to pay attention to other students who were presenting, because they kept working right up to the time their group member was to present.

Thus, a hands-on, design-based learning module works well from both the students' and teacher's perspective. Overall, students demonstrated an advanced stage of documentation. Scaffolding for documentation was appropriate and encouraged behavior and boosted skills in documenting ideas and work. Students developed significant skills in presenting their work. A majority of students were able to do a lot of idea generative thinking.

At the end of the unit, the teacher stated that the class that was perceived to be low-achieving actually learned more and were more engaged than the students in the class perceived to be high achieving. Specifically, the level of engagement, the level of team performance, and the thoroughness of student documentation were higher in the low-achieving class.

As further support of this teacher perspective, both researchers' observation logs showed high level of engagement in the low achieving class. When this observation was mentioned to the teacher, he agreed that students who previously had problems paying attention in class and remaining engaged were attentive and fully engaged during the implementation of the alarm design module.

Summary

In this study, students were asked to build engineering prototypes, typically working in teams to solve real design problems, following an authentic, reflective engineering design process. The findings presented two aspects of learning: engagement and achievement. Engagement has the potential to highlight students' performance in a way that standardized assessment methods do not reveal.

Achievements

According to the results of the knowledge tests, a wide range of students improved their understanding of electricity concepts. Specifically, these results revealed that African-American and free/reduced lunch students gained significantly more than the others. Similarly, we observed high achievement among African-American and free/reduced lunch students during the lessons. The improvement of these two groups of students suggests that design-based learning assisted all students and reduced the often-cited achievement gap. These findings strengthen previous research regarding the advantages of DBL to understanding scientific concepts (Kolodner, 2002, Rivet & Krajcik, 2004).

Although the results from the knowledge test do not show a significant improvement of low-achievers compared to high-achievers, the other research tools suggest that low-achievers achieved the same level of knowledge as the high-achievers. From the peer and teachers assessment, we found that low-achievers presentations were scored significantly higher than the presentations of the high-achievers scored.

It seems that standardized tests, such as the knowledge test used in this study, should not serve as the only tool to assess students' achievement. The observations and the portfolios showed that the low-achievers reached similar levels of understanding scientific concepts despite doing poorly on the pen-and-paper test. For example, the "Oh-snap" team (from the low-achieving class) said during the presentation of their alarm system: "We succeeded in building a model for our alarm system to a certain extent." This statement suggested that the students may have realized that the actual alarm system they have constructed satisfied the design process they documented. In the workshops and in other classes, the researchers have noticed that high achievers are used to waiting for the teacher's instructions such as what to do next, how to do it, which components to use, and so forth. When the "freedom to learn" is given to low achievers, they might adjust their learning process and could be more creative. The learner-centered module that was implemented in this study might thus assist them to reach higher levels of achievement. The assessment should capture their creative outcomes and should be sensitive to these achievements.

Engagement

The results from the observation of class activities and the analysis of the performance of low-achievers versus high-achievers strengthens past research regarding the advantages that project-based learning has (Barak, Waks & Doppelt, 2000; Doppelt, 2003). Project-based learning in a rich science-technology learning environment requires investigating new approaches for the evaluation of the learning process (Dori & Tal, 2000). Students who study using an authentic problem, integrate science, technology, and other aspects, reach a level of thinking that requires a reevaluation of traditional curricula (Barton, 1998) and assessment.

Our discoveries reported herein, and repeated in other schools, about the advantages of letting students construct circuits without formally teaching them about parallel or series circuits need further research. It is worth noting that one recent study found that only 51% of students who complete an introductory university physics course understood the concepts of series circuits and only 18% understood the concepts of parallel circuits (Aalst, 2000). According to our findings, students better understood parallel circuits when they intuitively constructed their circuit without preliminary instruction about them. Furthermore, they did not understand less about the series circuit. It seems that teaching series circuits first as is commonly done in most science curricula is in contradiction with students' prior knowledge and natural thinking. Using students' pre-knowledge and free exploration in order to teach them scientific concepts may have the advantage of engaging more students in the learning process and advancing their achievements. These findings suggest that further research is needed, aimed at exploring what is the best method to teach electrical circuits.

Design-based learning environment

Combining quantitative and qualitative tools in the same study can assist researchers to gain broader perspective on the learning environment (Fraser, 1998; Fraser & Tobin, 1991). The findings from this study suggests that DBL has the potential to increase students' desire to learn, enhance students' success in science class, and increase students' interest in science topics. Indeed, we observed students to be quite engaged in DBL, and the low-achievers explained scientific concepts at a level that their teacher had never observed them accomplish before. In addition, students gained in-depth experience in design activities and created meaningful technological outcomes, both from the product perspective and from the documentation and reflection perspective. Thus, design-based science has the potential to advance students' understanding of science (Fortus, et al., 2004).

This paper presents part of a larger study in which the electrical alarm systems module was implemented. Through intensive observations in the classrooms and discussions with teachers, it served as an initial stage for the researchers to study the impact of the developed module on engagement and achievement. The learning module and the research tools were improved and implemented in the second year. Thus, applying a new curriculum in a collaboration of researchers and teachers could have contributed to the success found here (Doppelt, Mehalik & Schunn, 2005; Zohar & Dori, 2003).

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A Comparison of Traditional and Hybrid Online Instructional Presentation in Communication Technology

Jeremy V. Ernst

Introduction

Online education has become a central element of the discourse on higher education (Cox, 2005). There seems to be an overall drive toward online learning given the mounting need for flexibility in scheduling and the daily emergence of communication technologies and capabilities (Hillstock, 2005). Online education is presented as a means of conveying instruction to an extensive learning community any place at any time. Cox (2005) indicates that advocates designate online learning as the driving force and model for transformation in teaching, learning, and formal schooling. Online courses have the potential to provide learners with individualized attention by the instructor, otherwise impossible in a large classroom environment (Environmental Education and Training Partnership, 2006).

With the continuing development of online instructional applications, many colleges and universities have begun to offer online courses as an alternative to traditional face-to-face instruction. Sixty-seven percent of colleges and universities agree that online education is the most logical long-term strategy for their institution (Hillstock, 2005). However, there are considerable hesitations rising, predominantly related to quality and student responsiveness to online education (Yang and Cornelius, 2004). Just as there are advantages there are also disadvantages to the online instruction delivery method. There is evidence through previous research that students feel isolated or disconnected when not engaged in traditional face-to-face instruction (Guhu, 2001; Graham, 2001), while other reports indicate large successes (Hoffman, 2002; Kaczynski and Kelly, 2004; Meyer, 2002). There remains a lack of clarity whether online courses are as effective as traditional courses (Poirier and Feldman, 2004).

While there has been a vast amount of research conducted on the advantages and disadvantages of online instruction, little is known on how assessment is used in online classrooms to monitor performance and progress (Liang and

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Creasy, 2004). Hew, Liu, Martinez, Bonk, and Lee (2004) describe the evaluation of current online education at three levels: the macro-level, the meso-level, and the micro-level. The macro-level is an online evaluation that assesses an entire online program, the meso-level evaluation assesses individual online courses, and the micro-level assesses the learning of online students.

Online courses present educational experiences very different from standard face-to-face environments (Hew, Liu, Martinez, Bonk, and Lee, 2004). When conducting a micro-level course evaluation, interest commonly lies in learner perception of the course experience pertaining to level of comfort, ability to communicate with classmates and the instructor, as well as a comparison to traditional face-to-face lecture. Many times the only means of evaluating learner perception is in the form of a questionnaire or survey. Although perception of online learning can be extremely useful information, it is usually not sufficient to conclude the evaluation without expanding it to learner understanding. The assessment of learner understanding assists in the determination of knowledge or skill acquisition at the conclusion of the course. Such information can be acquired through administering end-of-course tests or some form of cumulative final assessment. This study focuses primarily on the micro-level of online education evaluation in a technology education imaging technology course with cross group comparisons with the same course in a traditional face-to-face learning environment.

Background

The College of Education at North Carolina State University appointed a committee to assess the structuring of existing resources and energy to best position the college to address its “critical priorities and initiatives” and highlight these in a strategic plan (Moore, 2006, August). Among the critical priorities are expanding access and improving learning through technology in the K-16 system by developing more effective use of digital technologies in the foundational areas of communication, innovative technology, and online education. These priorities are subcomponents of the College of Education’s initiative to strengthen teacher education in science, mathematics, and technology education. The Mathematics, Science, and Technology Education Department at North Carolina State University was highly encouraged to implement online education initiatives.

Undergraduate students majoring in Technology Education at North Carolina State University experience a range of content organized into courses based around systems such as construction, communication, manufacturing, and transportation (North Carolina State University, 2007, March 13). The communication systems courses consist of a course in imaging technology and a course in broadcast communications. Imaging Technology is a four credit hour course recommended to be taken by technology education majors with a teaching licensure concentration during their first year enrolled in the program. The course exposes students to design, layout, and composition applications along with laboratory experiences. The purpose of the Imaging Technology course is to develop technical skills and the ability to apply knowledge and understandings of technical processes associated with graphic communications. Skill and understanding are acquired through studying content associated with and completing learning activities in finishing processes, screen printing, image development and layout, and digital photography.

The finishing process involves generating image ideas for use with a die cutter. Students take, scan, develop, or combine original images and import them into image processing or manipulation software. The image print size is modified to correspond with the chosen die, finalized, and printed. Backing is applied to the image and run through the die cutter, producing a simulated consumer product. A second idea generation process involves the generation of potential image solutions for a button design. Students again take, scan, develop, or combine original images and import them into image processing or manipulation software in which the image print size is modified to adhere to material constraints. The image is then finalized, printed, cut in a circular shape, and stamped using the overlays, facing, and backing. The screen printing process also involves an idea generation element where designs are sketched, scanned, or combined and imported into image processing or manipulation software in which the image print size is modified to correspond with the desired fabric size. The image is finalized, printed, exposed, developed, fixed to a screen, attached to the carousel, inked, and squeegeed to producing a print. The image development and layout laboratory exercise requires the development of a tri-fold layout, integrating the elements and principles of design. The topic of the layout is determined prior to the collection and generation of images and text. The completed tri-fold is burned to a CD. Additionally, a jewel case insert and CD label is designed and printed. The digital photography learning activity requires students to utilize a digital camera to take pictures using a variety of settings, movements, and techniques. Practice shots as well as required shots are specifically noted. The activity also involves image enhancement such as eliminating red-eye, cropping, merging, etc.

The introductory communications systems course was selected to initially explore online possibilities largely due to previous research in technology education concerning online education. Flowers (2001) concluded that we as technology teacher educators should "take advantage of the perceived need for online education …… [in] areas such as 'information and communication' and 'technological design'." In this study, Flowers found that interest levels for courses or workshops based on information and communication technologies were greater than any other content area included in the ITEA standards.

Methodology

The research design employed in this study is a quasi-experimental post-test only design. The structure of the study is similar to that of an experimental design, but did not use random assignment in the selection of participants. This micro-level course evaluation is used to assess the learning of hybrid online students through the use of a post-assessment and compare their learning to students who participated in a traditional lecture course supplemented with laboratory activity.

In the fall semester of 2006, a group of 23 students were selected to participate in the study. The group was enrolled in the Imaging Technology course described earlier. The intent of the course projects was to enhance understanding of how visual art and technology principles are combined to communicate effectively. The group met twice a week for fifteen weeks in a traditional face-to-face learning environment with an instructor-directed laboratory component. After each traditional face-to-face content lecture, students were given time to ask questions concerning the newly covered content. To conclude the course, a comprehensive final examination composed of 50 assessment items was administered to the students. Items were corrected and raw scores were calculated.

In the spring semester of 2007, an additional group of 23 students were selected to participate in the research study. This particular group was chosen to serve as the treatment group based on the vast similarity in demographical breakdown with the initial group of 23 students. Equality between the initial group of 23 and this additional group of 23 was controlled by matching characteristics of the participants such as gender, age, and major. The additional group of students was enrolled in the same imaging technology course under the same instructor. The group was scheduled for an online lecture once a week, supplemented with an instructor-directed laboratory once a week for a total of fifteen weeks. The students were not informed of the course format prior to registering for the imaging technology course. The online video lectures were accessible by the students via their course website. The video lectures consisted of narrated PowerPoint files converted into compressed media files. At the conclusion of each video lecture, students were prompted to submit questions concerning the newly covered content through an electronic posting system. After the completion of the online lectures, students were administered a hybrid online survey. The willing student participants completed the survey. To conclude the course, students were administered the same 50 item comprehensive final examination as the students who participated in traditional instruction. Items were corrected and raw scores were calculated. The comprehensive examination raw scores were entered and analyzed for differences and associations. The objective of this study was to identify the level of achievement of students based on the mode of instructional presentation of course content. This study utilized a post-only assessment of the two groups of interest. Cross group comparisons were made to identify variations in attainment.

Instrumentation

Two basic instruments, developed by the researcher, were used in this study. A 50-item cumulative assessment was used to measure student achievement. The assessment was composed of 10 multiple-choice items, seven true or false items, 19 matching items, four image matching items, and 10 image performance items. A researcher-developed hybrid online survey was used in the study to gauge perception and collect information associated with past experiences of students enrolled in the online content lecture imaging technology course. The survey consisted of items used to collect information on the following:

- if the students have taken an online course before
- if the students have taken a hybrid online course before
- student comfort in an online environment
- student perception of content covered in the hybrid online format and traditional lecture format
- student ability to effectively communicate with instructor
- student ability to effectively communicate with classmates

The survey questions were generated to establish learner perceptions pertaining to the method and structure of the hybrid-online instructional approach, while the cumulative assessment was used to collect information on learner understanding. Student perception and understanding are both central to micro-level course evaluations (Hew, Liu, Martinez, Bonk, and Lee, 2004).

Demographic Information

The two groups in this study total 46 university student participants, with 23 in each group. The two groups represent a variety of majors ranging from technology education to engineering. The majority of students in the traditional instruction group were technology education majors. Much like the traditional instruction group, the online instruction group was predominately composed of technology education majors. The 46 participants were predominately male. The study included only four female participants, three in the traditional instruction group and one in the online instruction group. The majority of the students in the traditional instruction group and the online instruction group were in the 18-20 age range, followed by the 21-23 range. Refer to Table 1 for a demographic comparison of the two groups.

Data Analysis and Findings

The hybrid online survey was used determine if students enrolled in the online content lecture imaging technology course have taken an online course before, taken a hybrid online course before, and feel comfortable in an online environment, feel the same content was covered in the hybrid online format as would have been in a traditional lecture format, feel they had the ability to effectively communicate with the instructor, and feel they had the ability to effectively communicate with their classmates. Twenty of the 23 student participants from the online instruction group completed the hybrid online survey, as it was completed on a voluntary basis. These data are reported in Table 2.

The majority of the student participants in the online instruction group had not participated in an online course (80 percent). Four of the 20 respondents (20 percent) indicated that they had participated in an online course during or prior to being enrolled in the imaging technology course. The majority of the student participants in the online instruction group had not participated in a hybrid online course (75 percent). Five of the 20 respondents (25 percent) indicated that they had participated in a hybrid online course during or prior to being enrolled in the imaging technology course.

Table 1
Demographic characteristics for the comparison groups

Characteristic	**Traditional Group** ***n*(%)**	**Online Group** ***n*(%)**
Gender		
Male	20(87)	22(95.5)
Female	3(13)	1(4.5)
Age Range		
18-20	12(52)	18(78)
21-23	9(39)	3(13)
24-26	1(4.5)	2(9)
27+	1(4.5)	0(0)
Major		
Technology Education	16(70)	16(70)
Graphic Communication	3(13)	3(13)
Engineering	2(8.5)	2(8.5)
Undeclared	2(8.5)	2(8.5)

The majority of the student participants in the online instruction group either agreed or strongly agreed (85 percent) that they felt comfortable in an online learning environment. Eighty percent of the respondents either agreed or strongly agreed that the same content was covered in the hybrid online format as would have been with the traditional lecture format. Fifty-five percent of the respondents strongly agreed that they had the ability to effectively communicate with the instructor, while 40 percent were undecided. Ninety percent of the respondents either agreed or strongly agreed that they had the ability to effectively communicate with classmates. These data are reported in Table 2.

A test of the following null hypothesis was conducted: There are no differences in overall cumulative achievement performance between the traditional instruction group and the online instruction group. The Kruskal-Wallis is designed to rank response elements from lowest to highest in the two designated samples (Hinkle, Wiersma, and Jurs, 1979) and was selected for this study. This test is an alternative to the One-Way Analysis of Variance when the measurement scale assumption is not met. This test, as with many non-parametric tests, uses the rank order of the data rather than raw values for statistical calculation. In this study, the imaging technology cumulative

Table 2
Degree of agreement: Online instruction group

Statement	Strongly Disagree n(%)	Disagree n(%)	Undecided n(%)	Agree n(%)	Strongly Agree n(%)
I feel comfortable in an online educational environment.	0(0)	1(5)	2(10)	12(60)	5(25)
The same content was covered in the hybrid online format as would have been in traditional lecture format.	1(5)	1(5)	1(5)	11(55)	6(30)
I had the ability to effectively communicate with the instructor.	0(0)	1(5)	8(40)	0(0)	11(55)
I had the ability to effectively communicate with my classmates.	0(0)	1(5)	1(5)	13(65)	5(25)

assessment raw scores were ranked. Based on the Kruskal-Wallis test, with an alpha value of .05, the calculated proportional value of 0.7313 indicated that the null hypothesis could not be rejected. Thus, there was no significant difference between the cumulative assessment scores of those enrolled in traditional instruction compared to those enrolled in the online instruction.

Discussion and Conclusions

The use of the hybrid online instructional approach presents student learning outcomes that are similar to those of traditional face-to-face instruction. The lack of learner outcome variation between the traditional instructional group and the hybrid online instructional group signals the establishment of concurrency between the two measures even though they are measures of the same construct. This investigation supports the use of a online instructional delivery structure to broaden the instructional audiences in technology education progams.

The use of online instructional delivery systems in technology education at the university remains at minimal levels as suggested by the 80 percent of online student participants, predominately technology education majors, who report that they have not taken an online course previously. Also, 75 percent of online student participants report that they have not taken a hybrid online course previously. The online lecture format does not seem to be widely embraced by faculty members currently serving or having previously served the student sample.

Hybrid online educational approaches afford students opportunities to investigate topics through authentic learning experiences while maintaining a highly collaborative structure (Doering, 2006). Any educational environment, online or traditional, that permits highly interactive instruction supplemented with practical applications of content provides a framework for successful acquisition of knowledge. The traditional content lecture remains a preferred method of delivery, but often fails to maximize the time and resources of faculty members and universities. Although online courses present very different educational experiences compared to courses that offer instruction in a traditional face-to-face environment, they can remain effective transmitters of information as evidenced in this study.

One-way compressed video lecture files were used as an initial investigational tool to explore the hybrid online format in this study. Advances in electronic instructional tools now allow collaborative and interactive communication with live video, document posting, presentation posting, sketch screens, and many other advanced features. Future exploration of the hybrid online format should utilize more advanced instructional tools.

Rumble (2001) notes that the technological history of distance education technology underpins its pedagogic history. Distance education is generally thought of as occurring in the absence of a teacher and presents some unique challenges for the lab component of technology education and its importance. Asimopoulos, Nathanail, and Mpatzakis (2007) note that courses with laboratory-based experiences facilitate comprehension through the use of hands-on practice and application. They further indicate that laboratory subjects suffer when an online education formats is used and practical study is omitted. The precise role of the teacher in laboratory environments should also be further investigated to determine the potential of providing hands-on learning experiences as a component of online instruction. Learning not only involves interaction with instructional content, but also interpersonal interaction in traditional and online environments (Berge, 1995).

Online education and its associated technologies have significantly changed the educational setting of higher education. Corresponding to the emergence of online education have been broad efforts to ensure the quality of educational offerings. For online education to be a widespread and effective vehicle of learning in technology education, continuous evaluation and assessment must be conducted. Measurement of educational outcomes as well as student engagement, comfort levels, and abilities to communicate must be continuously monitored to ensure quality and to maximize student achievement. Just as Ndahi (1999) concluded, online learning is not a substitute for face-to-face instruction, Rather, it should be an additional means for instructors to enhance their courses. The success of online education depends on the willingness and readiness of faculty to explore and develop online options and constantly monitor their effectiveness. The findings from this micro-level evaluation study further support the need for continued research in hybrid online instruction and delivery systems for laboratory instruction in technology education.

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Cognitive Processes of Students Participating in Engineering-focused Design Instruction

Todd R. Kelley

Introduction

Since the publication of the Standards for Technological Literacy in 2000 (ITEA), there have been a number of new programs developed that are designed to teach pre-engineering. Project Lead the Way is one such program. Project Lead the Way boasts serving over 1250 schools in 44 states and teaching over 160,000 students (McVearry, 2003). Efforts are also being made to infuse engineering design into technology education programs. One example of this is the work of the National Center for Engineering and Technology Education (NCETE) partnering with high school technology educators in summer in-service workshops to help teachers develop activities and curriculum to instill engineering design into technology education programs. According to Douglas, Iversen, & Kalyandurg (2004), the engineering community has identified the need for teaching engineering in K-12, and this has been supported by the American Society of Engineering Education (ASEE). The ASEE research analyzed the current practices of K-12 engineering education. The study stated:

> Clearly, there is a societal argument for the need for engineering education in our K-12 classrooms, as technical literacy promotes economic advancement. There is a statistical argument, as the number of students entering engineering schools declines, related to overall enrollment, and the number of women and underrepresented minorities in engineering remains well below the national average for higher education (Douglas, Iversen, & Kalyandurg, 2004, p. 3).

The engineering education community has identified the important role K-12 education plays in the success of post-secondary engineering education. Teaching engineering content in technology education programs has become a recent popular trend with curriculum initiatives such as Project Lead the Way, but some states, like New York, have had a course called “Principles of Engineering” since the late 1980s (Lewis, 2005). Teaching engineering design in K-12 might possibly be good for post-secondary engineering education, but does it produce technological problem solvers who have the ability to properly manage an ill-defined problem and develop viable solutions?

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Understanding the cognitive strategies of technical problem solvers is critical to developing curriculum that develops technologically literate individuals. The Standards for Technological Literacy (ITEA, 2000) identified the important role of cognition in design by stating:

> To become literate in the design process requires acquiring the cognitive and procedural knowledge needed to create a design, in addition to familiarity with the processes by which a design will be carried out to make a product or system (ITEA, 2000, p. 90).

Roberts emphasized "the purpose of teaching design is not to bring about change in the made world, but change in the student's cognitive skills" (1994, p. 172). Furthermore, ill-defined problems are more difficult to solve since they require more cognitive operations than simpler, well-defined problems (Jonassen, 2000). Johnson (1992) suggested a framework for technology education curricula, which emphasizes intelligent processes. "Students should acquire a repertoire of cognitive and metacognitive skills and strategies that can be used when engaged in technological activity such as problem solving, decision making, and inquiry" (Johnson, 1992, p. 30). Cognitive and metacognitive skills are important thinking processes required for problem solving, and these skills should be taught to students in technology education courses. Careful examination of the cognitive processes employed by students as they work through an ill-defined technical problem provides a means of evaluating the effectiveness of a curriculum approach designed to develop effective problem solvers.

Clearly, engineering-focused programs using a classic engineering design process model approach the design process differently than technology education programs using the design process featured in the Standards for Technological Literacy (Hailey, Erekson, Becker, and Thomas, 2005). The most notable difference in the design process is that engineering design uses analysis and optimization for the mathematical prediction of design solutions. In contrast, the technology design process emphasizes selecting a design idea, testing the idea through model building, and making final design decisions based upon a trial and error process. These vast differences in the approaches to design causes one to wonder if students from these technology education approaches to design instruction will be able to solve ill-defined problems using an engineering design process. Moreover, although both PLTW and the NCETE seek to develop engineering-focused design, the purposes of these programs are different. Consequently, so are their approaches. While Project Lead the Way (Project Lead the Way, 2006) is described as a pre-engineering program, the National Center for Engineering and Technology Education seeks to develop activities to infuse engineering design into technology education (Hailey, et al., 2005). Both engineering-focused approaches to design instruction seek to provide students with a systematic problem solving method through the application of the engineering design process, but will high school students from these two different groups perform differently when solving the same ill-defined problem? The purpose of this research was to determine if these two different approaches to engineering-focused design instruction will affect how students solve ill-defined problems.

Research Questions

This research study examined the cognitive processes employed by students participating in two different engineering-focused curricular approaches to design and problem solving. The following research questions guided the study:

1. Are students in the selected programs (NCETE & PLTW) using similar cognitive processes as they solve ill-defined problems?
2. Will students in the selected programs (NCETE & PLTW) perform similarly when presented with the same ill-defined problem to solve?
3. What cognitive processes are missing from students participating in the two different programs (NCETE & PLTW) and how does each group differ?
4. Are there important cognitive processes missing from students' performances in both groups (NCETE & PLTW)?

It is critical to closely examine these important questions as the field of technology education considers engineering design as a focus alongside the need for developing technological literacy in K-12 learners, a notion supported by leaders in the field of technology education (Daugherty, 2005; Lewis, 2004; Wicklein, 2006). This research examined how a high school student who has learned engineering design solves an assigned ill-defined technical problem. This insight can be helpful to develop further curriculum in technology education that will develop individuals who are technologically literate and effective problem solvers. Another benefit of this study is to gain insight into how a high school student, who has learned engineering design methods, manages cognitive processes as he or she engages in problem solving when confronted with a time constraint. Finally, it is beneficial to identify where students fail to properly manage cognitive strategies and to identify what cognitive strategies are not utilized in the problem solving process.

Participants

This research study examined students participating in two different engineering-focused design instruction: Project Lead the Way and a technology education program seeking to impart engineering design (NCETE partner). For the latter group, four participants were drawn from programs of a participating teacher in NCETE in-service workshops conducted at North Carolina A&T University. Three subjects were selected from Project Lead the Way schools by recommendation from North Carolina A&T NCETE partners. The Project Lead the Way participants completed the course Principles of Engineering and were currently enrolled in the capstone course titled Engineering Design and Development, which is typically taught to seniors in high school. The participants selected from a technology education high school program not using Project Lead the Way curriculum were students who were taught by an instructor who had benefited from the NCETE in-service teacher workshops during the summer of 2006. The participants from both groups were selected by their instructors for their problem solving abilities and willingness to participate in the study. It is important to note that the NCETE partnered school was currently generating new curriculum with a focus on engineering design which is why many course titles may not appear to reflect an engineering design focus; see Appendix B (available online at scholar.lib.vt.edu/ejournals/JTE/). The researcher selected participants for both groups who were homogeneous in educational background by requiring the same criteria for the prerequisites of mathematics and science as defined by the Project Lead the Way program (Project Lead the Way, 2006). The researcher conducted the study near the end of the semester so the participants gained as much training on engineering design as possible. Demographic information for the participants can be found in Appendix B & C. General demographic information about the instructors, curriculum, class size, and course titles can be found in Appendix D & E. (all appendices available online at scholar.lib.vt.edu/ejournals/JTE/)

Methodology

This study compared the cognitive processes used by the participants from the two curricular approaches to technology education as they used a design process to work through an ill-defined technical problem. The same ill-defined technical problem was presented to all the participants. Each participant was asked to carefully read the technical problem, identify all constraints he or she imposed on the problem, and then asked to begin to develop a solution. Each participant worked in isolation from other participants or classmates. The study used a "think-aloud" protocol method used in similar studies (Ericsson & Simon, 1993; Kruger & Cross, 2001; van Someren, van de Velde, & Sandberg, 1994). Atman & Bursic (1998) suggested that using a verbal protocol analysis for assessing cognitive processes of engineering students is a powerful method to understand the process students take when developing a design solution. Atman and Bursic stated: "analysis of a verbal protocol enables us to look at a subject's process in detail rather than simply 'grading' a final solution. That is, we can now grade the 'process' as well as the final design" (Atman & Bursic, 1998, p. 130). Moreover, verbal protocol analysis has been endorsed as a sound method for capturing and assessing engineering student's design processes (Atman & Bursic, 1998). Consequently, the participants were asked to verbalize their thoughts as they worked through the ill-defined problem. The researcher prompted participants to keep talking through the problem when he or she stopped verbalizing his or her thoughts; beyond this, the researcher did not interact with the participants. The participants were given a total of 30 minutes to work through the early stages of the engineering design process; however, several participants' sessions did not use the entire time. Although this time constraint limited engagement in the engineering design process, it was adequate to study how the student framed the problem and began to develop an initial design plan. The data collection included frequency and duration of time of the various mental processes allowing the researcher to break coding data into units of time including time on code, total time on each code, percentage of time, and total time of the testing session. This method of organizing data by time has been used in similar problem solving studies (Welch, 1999). Frequency was also recorded, tallying each iteration of the cognitive strategy used by the participant. Group mean scores were computed and reported for all cognitive processes used for both groups (see Tables 3 & 4).

The open-ended problem that was given to the participants described typical conditions in underdeveloped areas of the world where the domestic water is often transported by women and girls. This activity often causes physical stress on these women and children, resulting in acute medical conditions. The problem statement provided some general information about current constraints on this problem as well as solutions that are currently being employed. The statement asked the participants to provide details about how they would proceed to develop strategies to improve the current conditions in these underdeveloped areas. The participants were asked to list all constraints that they imposed on the problem. The problem that the participants were asked to solve is presented in Figure 1.

Framing the Problem

This study only examined the early stages of the design process. Certainly in the time constraint of thirty minutes, a student was unlikely to reach the final stages of the design process; therefore he or she was also unlikely to employ all of Halfin's (1973) mental processes. However, one of the most important stages of the engineering design process occurs at the onset of being presented with a technical problem: 'framing the problem' is this important stage. Experts in the field of design identify that framing the problem is a critical step to the design process and occurs as soon as the designer is presented with a technical problem (Dym, Agogino, Eris, Frey, & Leifer, 2005; SchÖn, 1983). This early stage of the engineering design process often finds engineers seeking to locate the problem space where the search for the solution begins, starting conditions are identified, and goals are stated. This problem space creates a partial structure from which a solution space can be formed. The solution space structure begins to be developed as ideas are generated; this structure is transferred back to problem space to again consider solution implications. This method seeks to generate cohesion of problem and solution (Cross, 2004).

Data Gathering and Analysis

The participants were videotaped for further analysis by the researcher. The tape was used to record each participant's voice as he or she verbalizes their thoughts, as well as to record any actions such as sketching, measuring, or any other non-verbal cues. Cross (2004) indicated that one weakness of the 'think aloud' verbal protocol method was that it was extremely weak at capturing non-verbal thought processes, using observation in combination with the 'think aloud' method was employed to help capture non-verbal cues. This technique of

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Problem

In certain underdeveloped areas of the world the majority, if not all, of domestic water is transported by women and young girls, causing considerable physical stress and resulting in medical conditions that are particularly acute during child-bearing and birth. Small villages are scattered throughout rural areas of the world where this has become a major issue, in part due to the steep mountainous terrain.

Currently, water is typically held in plastic or metal vessels and carried in the arms, balanced on the head, or attached to the ends of a rod and carried across the shoulders. Families who can afford beasts of burden (mules, camels, cattle, etc) employ them in this activity, although this is the exception.

Cultural and political constraints often hinder installation of modern water management systems; therefore temporary measures are needed to improve current conditions.

Your Task:

Describe how you would proceed from this problem statement in order to improve the current condition in these underdeveloped areas. Please list all constraints that you impose on this problem. As you work through this problem, ‘think aloud’ your strategies for deriving a solution.

Figure 1. The ill-defined problem used in the study.

combining a verbal protocol with a video of the testing session is known as observational protocol and is a data collection method used to assess student design and problem solving strategies (Laeser, Moskal, Knecht, & Lasich, 2003). The data collection included frequency and duration of time of the various mental processes.

This research study focused on cognitive processes from a list of 17 mental processes that were identified by Halfin (1973). Halfin used writings from ten high-level designers including Buckminster Fuller, Thomas Edison, and Frank Lloyd Wright. Halfin used a Delphi technique to identify mental processes that were universal for these expert engineers and designers. Hill (1997) developed a computer analysis tool called the Observation Procedure for Technology Education Mental Processes (OPTEMP) to assess problem-solving activities in technology education by employing Halfin's code of mental processes. The study herein used a revised and updated OPTEMP computer program to assist in coding and recording the frequency and duration of time of the cognitive processes employed by students as they worked through the selected ill-defined technical problem. The researcher coded the actions and cognitive processes used by each participant as he or she worked through the technical problem. The number of frequencies and the time spent on each strategy were compiled and a total was recorded in the OPTEMP output.

Microsoft Excel software was used to process the data files generated by the OPTEMP program. Careful analysis of the percentage of time and frequency spent on the various cognitive strategies provided insight into mental processes employed by the students as they worked to frame the ill-defined problem as well as a comparison of group means scores.

Table 1
Halfin's (1973) Original Cognitive Processes

Mental Methods	Code
Analyzing	AN
Communicating	CM
Computing	CO
Creating	CR
Defining problem(s)	DF
Designing	DE
Experimenting	EX
Interpreting data	ID
Managing	MA
Measuring	ME
Modeling	MO
Models/prototypes	MP
Observing	OB
Predicting	PR
Questions/hypotheses	QH
Testing	TE
Visualizing	VI

Findings

Although a thirty-minute or shorter examination is inadequate in understanding the entire process taken by problem solvers, it can provide great insight into an individual's ability to organize the problem, constraints, and criteria in order to begin developing a solution. Importantly, the reader is reminded that the findings of this study are very limited in their generalizability.

Are students in these different programs using similar cognitive processes as they solve ill-defined problems?

The research revealed that both groups used similar cognitive strategies as they worked though the ill-defined problem. Both groups employed at least six of the ten mental processes that were identified in the test sessions. The cognitive strategy analysis (AN) was the most common mental processes employed. This code was recorded when the researcher witnessed the participant breaking down the problem and identifying constraints and criteria. The participants spent from 19 to 54 percent of their time doing this. The group mean was 10.70 minutes for the PLTW group and 7.42 minutes for the NCETE group. The duration of time that the two groups spent on the various strategies varied considerably (See Tables 2 -4).

Will students in these programs perform similarly when presented with the same ill-defined problem to solve?

The results of this research revealed that the two groups did perform differently with respect to time spent developing solutions (coded DE). Often this mental process is considered the most critical in determining how an individual designs a solution. Kruger and Cross (2001) proposed that designers are either solution driven or problem driven. Welch and Lim (2000) have noted that novice designers often become stuck in the problem space and fail to generate solutions. The results of this study reveal that group NCETE partner group spent more time generating solutions than the PLTW group. The NCETE group spent from 18 to 32 percent of their time designing and talking about solution ideas. In contrast, the PLTW group only spent from 3 to 8 percent dialoging design solutions. Comparing the group means, the NCETE group spent an average of 5.40 minutes generating design solutions in contrast to an average of 1.77 minutes spent by the PLTW group. Although creative designers are known for generating multiple solutions, there is a danger in generating solutions too quickly due to an incomplete understanding of the problems (Welch, 1999). It is important to consider that while the NCETE group spent more time generating solutions, the PLTW group spent a considerable amount of time defining and analyzing the problem. Comparatively, architects are problem solvers who generate multiple solutions to design problems, whereas engineers are often trained to locate a single solution that works in a timely and cost effective manner (Akin, 2001). Although participant number six developed only one design idea, eight frequency counts are reported (Table 2) and represent discussions of a single design idea. Participant number six was convinced that the idea was the best solution, possibly based on his knowledge of similar cultures who have struggled with this problem. Ball, Ormerod, & Morley (2004) refer to this approach to solving problems as “case-driven” and refer to it as a novice designer approach. The case-driven approach is used to quickly move to a solution by recognizing the similarity of the current problem to a problem encountered in the past and to apply a solution from the earlier

Table 2
Frequency and Time Spent in Halfin's Mental Design Processes within the NCETE Partner School Group
f =frequency, T= time, %T percent of time

	Participant #1			Participant #3			Participant #3			Participant #4		
Halfin's Code	***F***	**T**	**%T**	***f***	**T**	**%T**	***f***	**T**	**%T**	***F***	**T**	**%T**
DF	15	6.22	22.07	16	5.30	19.26	4	1.58	12.89	22	5.09	20.15
AN	33	5.23	18.56	34	11.37	41.32	22	5.01	40.86	63	8.05	31.87
DE	43	8.58	30.45	20	5.10	18.53	14	3.31	27.00	33	4.59	18.17
MA	16	2.27	8.06	0	0	0.00	1	0.39	3.18	11	1.55	6.14
PR	4	0.37	1.31	8	2.11	7.67	6	1.56	12.72	20	2.36	9.34
QH	0	0	0.00	12	2.56	9.30	2	0.41	3.34	1	0.04	0.16
CM	6	0.58	2.06	1	1.08	3.92	0	0	0.00	0	0	0.00
MO	12	4.13	14.66	0	0	0.00	0	0	0.00	20	3.01	11.92
CO	0	0	0.00	0	0	0.00	0	0	0.00	1	0.17	0.67
ID	1	0.40	1.42	0	0	0.00	0	0	0.00	0	0	0.00
Total	130	28.18	100	91	27.52	100	49	12.26	100	171	25.26	100

problem. Conversely, Cross (2004) suggested that expert problem solvers with experience in designing move quickly from the problem frame to proposing a solution. Considering that this participant spent a great deal of time identifying the constraints and criteria (analysis) and very little time simply defining the problem, he may be demonstrating his ability to design quickly and efficiently as opposed to lacking creative idea generation (See Table 3).

What cognitive processes are missing from students representing the two different programs, and how does each group differ?

Of Halfin's 17 mental processes, seven processes were never employed by either group. A close examination of the seven missing processes resulted in a a logical explanation for most of them. For example, models/prototypes (code MP) were never employed, quite possibly due to the limited time constraints and lack of available modeling materials. Actually, use of models and prototypes was not expected by the researcher at this stage of the design process. Interpreting data (ID) was not often employed by participants (only one participant used it to a very limited extent) in this study. This is likely due to the fact that there were little data to interpret from the problem statement.

Measuring (ME) was a mental process that could be applied to this ill-defined problem if a heuristic (as suggested by Koen, 2003) was applied to the constraints presented in the problem. However, none of the participants employed this strategy. Measuring, as defined by Halfin is "the process of describing characteristics (by the use of numbers) of a phenomenon problem, opportunity, element, object, event, system, or point of view in terms, which are transferable" (1973). Considering that a major distinction between the technology and engineering design processes is that engineering design applies mathematical prediction and optimization, this missing cognitive process is significant. The absence of this cognitive strategy causes one to speculate whether or not students in an engineering-focused design program have any increased ability or need to use mathematics to predict design solution compared to students from technology education programs without an engineering design focus, at least with respect to solving an ill-defined problem. Thus, this study does not support the notion that students in an engineering-focused program apply mathematical prediction and optimization in their problem solving. The other missing cognitive processes from both groups included creating (CR), experimenting (EX), observing (OB), testing (TE) and visualizing (VI).

Are there important cognitive processes missing from students' performances in both groups?

As mentioned above, measuring (ME) was never utilized by any participant in the study. Computing (CO) was only used by two participants, one from each group applied a quantity to estimate potential distances traveled or the altitude of the mountain terrain. However, no participants used estimations to predict the results of design solutions. This has been identified as a missing piece in the technological design process (Hailey, et al., 2005; Wicklein, 2006). The

Table 3
Frequency and Time Spent in Halfin's Mental Design Processes within the PLTW School Group (f = frequency, T = time, %T = percent of time)

Halfin's Code	Participant #5			Participant #6			Participant #7		
	F	T	%T	*f*	T	%T	*f*	T	%T
DF	8	2.56	9.02	9	2.17	18.08	38	7.24	27.23
AN	168	13.39	47.16	55	4.53	37.75	91	14.18	53.33
DE	22	2.56	9.02	8	0.40	3.33	19	2.34	8.80
MA	2	0.16	0.56	12	1.57	13.08	11	1.46	5.49
PR	33	6.05	21.31	17	2.10	17.50	11	1.24	4.66
QH	0	0	0.00	1	0.13	1.08	1	0.13	0.49
CM	0	0	0.00	1	0.7	5.83	0	0	0.00
MO	13	3.11	10.95	0	0	0.00	0	0	0.00
CO	3	0.16	0.56	0	0	0.00	0	0	0.00
ID	0	0	0.00	0	0	0.00	0	0	0.00
Total	247	28.39	100.00	103	12.00	100.00	171	26.59	100.00

Table 4
Comparison of Times and Frequencies for PLTW and NCETE Participants by Halpin's Categories

	Frequency		Time	
	NCETE Group	PLTW Group	NCETE Group	PLTW Group
DF	14.25	18.33	4.55	3.99
AN	38.00	104.67	7.42	10.70
DE	27.50	16.33	5.40	1.77
MA	7.00	8.33	1.05	1.06
PR	9.5	20.33	1.60	3.13
QH	3.75	0.67	0.75	0.09
CM	1.75	0.33	0.42	0.23
MO	8.00	4.33	1.79	1.04
CO	0.25	1.00	0.04	0.05
ID	0.25	0.00	0.10	0.00
Total	110.25	173.67	23.31	22.33

minimal use of this cognitive strategy should be a concern for those who believe students in engineering related programs have the ability to apply their math skills to predict design solutions.

Reliability

The measure of inter-coder reliability revealed a high degree of consistency. Two researchers independently coded 10 % of four of the seven protocols as outlined by Evans (1995). Segments were selected at the beginning, middle, and at the end of the assessed protocols to ensure that the reliability check was conducted at various stages of the testing session. The total times that each coder ascribed to Halfin's mental processes are presented in Table 5. Standard deviations ranged from .523 for Analysis to .092 for Managing and Predicting.

Table 5
Inter-coder Reliability Agreement Results

	Time		
Halpin Category	**Coder #1**	**Coder # 2**	**Standard Deviation**
DF (Defining the Problem)	4.41	4.53	0.085
AN (Analysis)	4.05	3.31	0.523
DE (Designing)	0.46	1.01	0.389
MA (Managing)	0.00	0.13	0.092
QH (Questioning)	0.21	0.15	0.042
CM (Communicating)	0.18	0.34	0.113
PR (Predicting)	0.13	0.00	0.092
Total Time	9.44	9.47	

Discussion

As the field of technology education has been moving to include engineering, a variety of new curriculum projects have emerged. Some examples of curriculum projects include Project Lead the Way, and ITEA's Engineering by Design, Engineering the Future, and Engineering is Elementary. As these engineering oriented programs are implemented into schools and new curriculum is implemented, it is important to evaluate their effectiveness in increasing students' cognitive abilities with respect to problem solving. One way to do this is to examine students as they work to solve ill-defined problems. The method used in this study can provide a heightened awareness of what is really happening in the minds of the students as they work to solve a problem. Technology education programs have often emphasized design and problem solving (Flowers, 1998; Foster, 1994; Plaza, 2004), but little research has been done to determine how effective these activities are in developing skills, skilled problem solvers, and excellent designers (Lewis, 1999). More research needs to be conducted in technology education to examine the cognitive capabilities of students and observational protocols are a sound methodology that is cost effective. According to the results of this study, students do perform differently with respect to solving ill-defined problems when grouped by engineering-focused programs. Additional research should be done to extend the results of this study by increasing the sample size and expand the sample to include other technology education programs with and without an engineering focus. It is critical for the field of technology education to consider the characteristics and outcomes it would like to develop in its students. Among these outcomes are students who are creative problem solvers who can generate multiple solutions on the one hand or problem solvers who can quickly locate the most efficient and cost effective solution on the other hand. Certainly, a case can be made for both types of problem solvers, quite possibly a blend of experiences in problem solving would be appropriate for the field to consider as the integration of engineering design continues.

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Moving Beyond Cultural Barriers: Successful Strategies of Female Technology Education Teachers

Raymond R. McCarthy and Joseph Berger

Women are underrepresented in Science, Technology, Engineering, and Math fields of study and careers with a subset of STEM—Technology Education—possibly one of the least integrated fields for women as students and as professionals (Akmal, Oaks, & Barker, 2004; Braundy, 2004; Braundy, Petrina, Dalley & Paxton, 2000; Zuga, 1996; Zuga, 1999). What accounts for this situation and what are potential remedies? The purpose of this study was to learn about the ways in which female technology education teachers understand sources of influence on their career choices. The findings from this study are intended to provide insights into the participants' perspectives that might shed light on how to better encourage females to aspire to and enter technology education as a profession. The conclusions derived from this study may help to create a deeper understanding of how women move beyond cultural barriers and make "unexpected transitions" to become female technology education teachers. This qualitative study is based on interviews with ten female technology education teachers.

This study is significant because little change has been made towards increasing female participation in STEM fields despite millions of dollars spent to overcome the shortage of women in STEM studies and careers (Haynie, 2005, National Education Association (NEA), 2003a; National Education Association (NEA), 2003b; National Science Foundation (NSF), 2002; National Science Foundation (NSF), 2003a; National Science Foundation (NSF), 2003b).

More young women need to be encouraged to pursue STEM careers, but cultural deterrents (Kandaswamy, 2003) to female inclusion in these fields are very resilient. Young girls need female technology education and STEM role models to guide them into these non-traditional fields since gender role modeling directly supports intellectual and emotional growth (Grant & Ward, 1992; Kandaswamy, 2003). Therefore, "trailblazers" (Schlossberg, Waters., & Goodman, 1995) need to be encouraged to strike out and mark some possible paths so that more women may feel empowered to participate in these fields.

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A literature review identified three primary factors related to women participating in male dominated professions:

Women were, and in some parts of the world still are, confined to hearth and home (Bassavage, 1996; Kandaswamy, 2003). However, for the past 250 years, American women and men have been working to advance gender equality (McCullough, (2001), Women's International Center (1997), Zuga, (1999).

Since its inception, America has turned the status quo upside down in governmental organization, technological advances, educational systems, and societal/cultural evolutions (McCullough, (2001), Women's International Center (1997), Zuga, (1999).

However, in spite of all these changes—including the women's liberation movement of the 1960s-1970s—girls and women are still not fully participating in male dominant STEM fields of study and work (Dick & Rallis,1991; NEA, 2003a, NEA, 2003b, NSF, 2002, NSF, 2003a, NSF, 2003b).

The gender inequity in these STEM fields confounds educators, researchers, and policy makers. A new paradigm, a change of focus, is essential; one that aims at something other than the efficacy of recruiting techniques (NSF, 2003) which succeed only marginally. New research is needed that investigates what "triggers" or pivotal events (Schlossberg et al., 1995) encourage women to become professionals in STEM careers. This investigation could use women's "ways of knowing" (Goodwin, 2000; Zuga, 1999) to identify different paths that girls and women can follow to gain better equity in high paying fields and help strengthen our country's future.

It has been documented that women who experienced STEM encouraging cultures—played with boys and "masculine" toys in their pre-school lives or looked up to same-gender role models in STEM related activities during their formative education—might be interested in pursuing technology related careers (Armstrong & Leder, 1999; Grant & Ward, 1992; Silverman & Pritchard 1996; Welty and Puck, 2001). Furthermore, research shows that there are many attempts to create recruiting programs to encourage girls and young women to consider studies and careers in STEM fields (NSF, 2002 & 2003a&b; Silverman & Pritchard, 1996; Welty & Puck, 2001) but these efforts seem to improve the situation only marginally. In this context, this study seeks to help identify pivotal points in young girls' lives: what are the causal events that "trigger" (Schlossberg et al., 1995) the commitment to the study of non-traditional subjects and eventual employment in related fields.

Conceptual Framework

The foundation for the conceptual framework is a construct derived from the work by Schlossberg (1984) and Schlossberg, Waters, & Goodman (1995) in combination with Kandaswamy (2003). While Schlossberg (1984) writes about transitions that adults go through in careers, relationships, and life changes, this study focuses on adult transitions as young women discuss how they chose to enter a specific male-dominated field, while also considering how the concept of transitions can be applied to the transformation of young girls to women. First, and perhaps most importantly, girls, from birth to womanhood, live through a long series of transitions defined by Schlossberg (1984) as "any event, or non-event that results in change anticipated, unanticipated … [in] relationships, routines, assumptions, and roles" (p. 47). These transitions are shaped by what Schlossberg, Waters, & Goodman (1995, p. 27) call "the theory of the "Four Ss"… situation, self, support, and strategies." Schlossberg et al. (1995) define:

- "Situation" as the way a person uses her past experiences and abilities to deal with transitions and make adjustments due to the changes.
- "Self" as the way a person is helped or at a disadvantage due to her personal attributes or resources in facing change.
- "Support" as the many support systems that help a person undergoing change.
- "Strategies" as the way a person responds when facing change (p. 113).

While the work of Schlossberg and her colleagues focused specifically on adult transitions, Kandaswamy (2003) stated that both girls and women must make choices and transitions that are typically confined to culturally accepted roles—such as mother, nurse, teacher, and secretary— that result from a series of transitions throughout their lives and are reinforced by "social myths, conditioning, the media itself, deterrence, and the problem of 'balancing.'"

Following this line of inquiry, the participants were asked to identify those stimuli that caused their life transitions that culminated with their becoming technology education college students and then teaching professionals. The following section details the research questions that produced the data for this inquiry.

Methodological Approach

This study was guided by three main research questions:

1. What are common themes in the female technology educators' lives and educational experiences that can shed light on more efficacious ways to increase the numbers of females participating in STEM fields and technology education in particular?
2. What strategies did these female technology education teachers develop to overcome the gender barriers blocking their chosen careers?
3. What steps do the participants believe should be taken to attract more women to technology education studies and careers?

In order to answer these questions, ten female technology education teachers were interviewed as part of a qualitative study. This approach was selected because "qualitative studies are…an overall strategy" that aims at getting deep, rich, descriptive data (Rossman and Rallis, 2003). Further, Rossman and Rallis (2003, p. 104) write that qualitative studies often focus on "psychological roots" when examining individuals. The participants' "roots" (p. 104) are at the center of this study with the interviews focused to examine how these women came to their choices in the midst of their transitions.

The ten women included participants who were initially identified through a local technology education association and then a purposive snowball sampling technique (Rossman & Rallis, 2003) was adapted as participants recommended additional female technology educators for inclusion in the study. Each of these women participated in two semi-structured interviews that were based on questions derived from the conceptual framework. The first interview focused on obtaining narrative data related to the three main research questions. The women subsequently kept a journal for fourteen days that focused on recollections of key transition points and sources of influence during their formative years. The second set of interviews followed-up on the preliminary analysis of the previously collected data. Finally, a focus group was conducted with three of the women as the basis for checking the data and findings to ensure authenticity and trustworthiness from the perspective of the participants.

The ten women ranged in age from twenty-five to fifty-six. They had taught technology education for a minimum of three years to a maximum of twenty-two years with a mean of fifteen years at the time of the study. Three were unmarried. All had earned at least a master's degree and four had earned either a Ph. D. or Ed. D. Eight participants were Caucasian, one was African American, and one was Chinese American. Participants were living and working in Connecticut, Massachusetts, North Carolina, Ohio, and Virginia. The participants were randomly assigned alphabetical aliases — no ethnic, socio-economic, or geographical connotations were connected with these names.

Results

The overall findings from this study suggest a complex model in which female technology educators make the transition into this male-dominated field as the result of the combined effects of support from others, situation specific contexts, and self-identified characteristics in conjunction with specific strategies that helped move them into their chosen careers. These concepts are represented in the Developmental Process Model in Figure 1. More specifically, our model, based on Schlossberg et al. (1995), attempts to illustrate the dynamic forces that prepared these women for their study and career choices. The "self" bubble depicted the participants as "tom boys" who were inquisitive, active, hands-on learners who did not feel that girls should be limited to "girlie" activities. The "situation" bubble showed that these females lived and learned in supportive, non-confining families, homes, and schools. The challenges were getting the type of experiences that these girls/young women craved while the benefits were those experiences in which they were allowed, even encouraged, to participate. The participants were aided and supported by fathers, grandfathers, and male technology education teachers in gaining experience and skills in these hands-on activities. Furthermore, the "support" bubble showed that teachers and professors as well as family members had influence in shaping these women’s futures. Only two members of the study had very supportive counselors (Brit said, “I never saw a counselor. I wouldn’t recognize them if I saw their pictures.” Five had similar experiences and all ten saw a need for better counseling. The “strategies” bubble symbolizes the intentional as well as coincidental ways the participants pursued their interests playing to their strengths. Several of the members of this study indicated that hands-on tool and material use were early interests and the term “technology” was slipped in as they became college students. The categories of support, situation, and self all influenced the strategies used by these women as they made transitions throughout their lives that led to their current roles as technology education teachers. Throughout these experiences and transitions, the participants described how they must continually balance their own sense of self, personal situations, and types of support in order to strategically make successful transitions into roles that are not traditionally supported for females in this society.

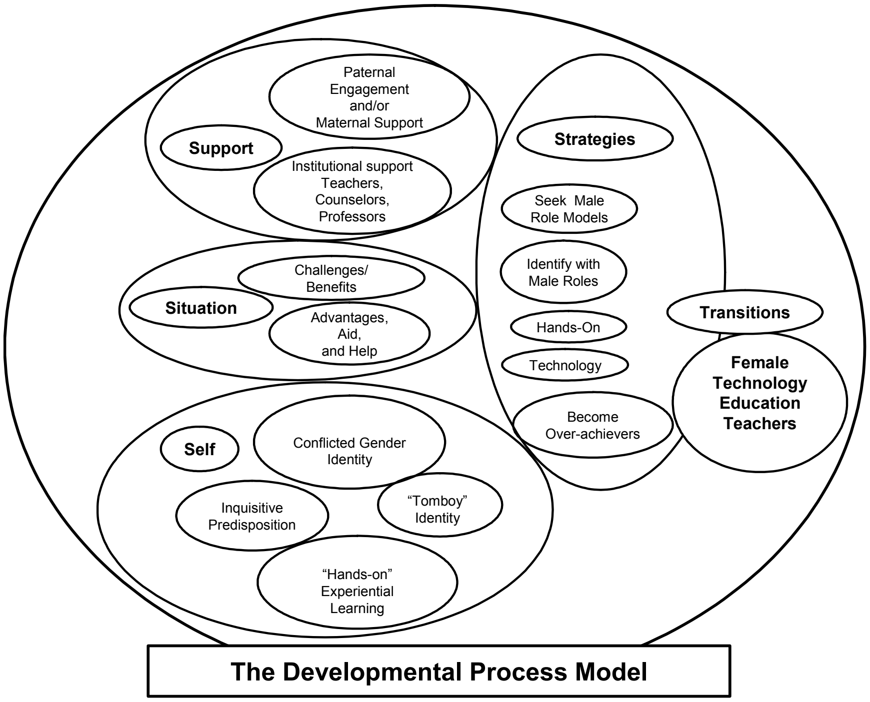

Figure 1. The Development Process Model for female technology educators

The “transitions” bubble represents the “non-event that results in change anticipated or unanticipated” (Schlossberg et al., 1995) that these participants felt concerning their choice of studies and careers. The participants all felt that their choice of study and career was natural without a sudden "Aha!" moment. All responded that they had been supported in their professional pursuit by a technology education teacher in their educational career, whether it was in middle or high school, college, or starting over in a second career.

In response to the first research question, "What are common themes in the female technology educators' lives and educational experiences that can shed light on more efficacious ways to increase the numbers of females participating in STEM fields in general and technology education in particular?", several evolving themes were identified from the interviews and journals. As summarized in Figure 1, early childhood self-identity, choice of play, and interaction with playmates seemed to prepare these women for comfort in interacting in male dominated contexts and experiences. Not surprisingly, family support and parental encouragement seemed to play a big role in allowing these women to feel more at ease in using tools and machines that are considered male objects in American culture. The data from this study indicate that direct and indirect male role modeling involving tool and machine use, workshops, and home-improvement activities appeared to have engaged the girls who later became proficient in tool use themselves. The participants in this study noted that mothers often served support roles. While mothers might not actually use the tools and build projects with the girls, they either encouraged their daughters to explore all sorts of non-traditional activities, or allowed the girls to investigate activities and educational experiences that interested them.

Since these women were interested in "non-traditional" activities and "guy" pursuits early in their lives, they needed to develop strategies (Schlossberg, et al., 1995) that both mollified apprehensive loved ones concerning their safety and allowed themselves to feel comfortable in pursuing their chosen fields of study. These women reported that fathers, grandfathers, and other male role models made positive connections early in these women's lives. These father/daughter moments were early strategies to get to do "active, not passive" things, like hammering, using tools, and playing football.

These positive early childhood interactions with men set a pattern for the girls/young women/women. By identifying well with adult males, male cousins, and male siblings while enjoying the interaction with the same, these girls "felt comfortable with fluid gender roles" and were able to slip in and out of the male world. Even today, participants agreed with Brit that "it's just maybe not being pigeonholed into one particular group." As these girls entered middle school, a few in private schools but most in public, they were still positively engaged with male relatives after school, on weekends, and in the summer.

All of the participants mentioned male technology education teachers with whom they had a special connection. Other recurrent themes in the interview responses include the recollections that male technology education teachers, in middle school, high school, college, or as professional colleagues took many of these girls/young women/women into mentor-protégé relationships when the teachers recognized, supported, and rewarded the women's talents, skills, and abilities in technological activities and related fields of inquiry.

These male teachers "took them under [their] wing" to support their technology education interest. For some of the respondents, the "trigger" (Schlossberg et al., 1995) point was in middle school, others in high school, still others in college. One participant found guidance and support for her conversion from teaching English to technology education by a soon-to-retire teaching colleague, finally two participants were certified Civil Engineers who decided to move laterally into technology education to satisfy a need to give back to the next generation. Consciously or subconsciously, these women sought male role models who could guide and support their studies and interests as most of the participants' fathers or grandfathers had done in their early childhood and youth. Further, intervention by guidance counselors was crucial for two of the study's members when the girls' interests did not line up with the traditional home economics or art classes; the guidance counselors said "go for it" in automotive shop and architecture.

One theme that appears to be central in understanding women in technology related fields is that these women were comfortable (as several participants, Anna, Brit, and Jan, mentioned) "being fluid in their own gender roles." Several women noted that female technology education teachers have to be many things to many people. Sometimes they are "one-of-the-guys," but in other situations, these women model to their students how women are able to interact with modern technology. These teachers report that males often surround them in typical lab experiences and they feel comfortable in this situation. As Brit said: "I'm a bit of an anomaly still, the female in the technology education department, and so people will say, oh, how is it working with all those guys? I say, well that's the story of my life, that's the way it is. My classrooms are filled with boys, but I don't spend time dwelling on it." In a later interview, she reinforces this with, "It doesn't faze me to be in a room that is full of boys."

At other times, these women have to solve design and equipment issues such as importing a graphic design while modeling problem solving behaviors to encourage girls to go beyond the girls' stereotypical beliefs ("a girl doesn't do that computer hardware stuff" (Cat). These women have developed multiple ways to interact with information, materials, tools, and learning, as well as being a "jack-of-all-trades (sic)." Since technology education covers such a wide range of skills and understandings, technology education teachers may have up to five different "preps" (different subjects to be taught, i.e. manufacturing, communications, drafting/CADD, research and development, and pre-engineering). These women have to be both knowledgeable in these subjects and overcome sex-role stereotypes while teaching the subjects. Indeed, technology education has been criticized (Leadership Forum discussions at the ITEA conferences, 2006 & 2007) because it is so hard to "brand" technology education because it has so many different skill sets and avenues of expression and understanding. However, these women who were able to be hands-on technology education teachers during the day and then get dressed up to go out to dinner in the evening have the ability to be comfortable in their skins at any given time.

In response to the second research question, “What strategies did these female technology education teachers develop to overcome the gender barriers blocking their chosen careers?,” all participants noted that they had to develop “strategies” (Schlossberg, et al., 1995) to be able to fulfill their need to pursue “non-traditional” activities and “guy” pursuits early in their lives. As the model depicts, these girls needed to develop systems of interaction with others that both appeased friends and relatives regarding their safety while they felt engaged and invigorated while playing, learning, and interacting with male peers and adults. Some of these women relied more on deliberate strategies, while others engaged in activities that were less consciously active, but in direct reaction to how their sense of self interacted with the situations and types of support they encountered while growing up.

The male role models who made positive connections early in these women’s lives encouraged their female protégés to explore and find success in hands-on activities. These girls’ earliest strategy to satisfy their innate drives to manipulate tools and materials while being active was to use the time spent with their fathers/grandfathers to be able to play the roles of dynamic, active people who could do things like tinkering with machines, using tools, and playing baseball and other “non-traditional” games and sports. These positive early childhood interactions with men set a pattern for the girls/young women/women. During the focus group discussion, Fiona said her “best memory of working with her Dad was roofing the summer camp…that was great!” Their early interactions with males gave these girls plenty of practice in being “comfortable with fluid gender roles” and were able to slip in and out of the male world. This slipping in and out of the gender role would become a lifelong strategy to help them to be, as Anna said, “comfortable being me.” Even after the girls entered primary education, they found time (recess, after school, and on weekends and vacations) to keep playing, working, and mixing with young and older males.

As these young women entered middle school and high school, they found some kindred spirits with male technology education teachers with whom they had a special connection. The strategy of finding male technology education teachers permitted the girls to continue their pursuit of kinesthetic, active, and rewarding activities. Consciously or subconsciously, these women sought male role models who could guide and support their studies and interests as most of the participants’ fathers or grandfathers had done in their early childhood and youth.

Another strategy to find success in the technology education field was to take on “male” roles in order to find success in these male dominated activities. Many of these women worked in business, construction, civil engineering, and cabinetmaking before transferring to technology education teaching. As Fiona said: “Most of my working career was predominantly with men. Even when I was doing part-time jobs in college…most of the time, it was with men. In business the majority of people that I worked with were men.” These women’s earlier jobs were hands-on and male oriented. The participants stated that these earlier work experiences helped to prepare them to teach mostly male students in technology education courses.

Further strategies that helped these women develop a positive sense of self included their enjoyment of hands-on activities, which led to hobbies (Brit: “I fooled around with model planes…” which led to studies, which led to employment (“My shop teacher hired me to work construction in the summers…,” explained Gina) and careers teaching technology education. These women developed more technological skills (in drafting, graphics/communications, engineering, and materials processing) as passage keys to move into “male oriented” careers.

One final universal strategy that participants used was to “over-achieve,” to demonstrate that they were equal to anyone in the field. While several women remembered having a tough time in some part of their schooling, the minute they focused on technology education in college and then in their careers, they channeled their energies to succeed. This over-achieving was identified in several ways. One way of going “above and beyond’ that the participants recognized was how long they stayed after school to offer extra help and to prepare the next day’s, week’s or units’ learning experiences. Male teachers were perceived to be less willing to do extra preparation or spend extra time. Women technology educators were also seen (by Anna, Brit, Fiona and Jan) as more willing than male co-workers to work and participate in local and national technology education societies such as the Technology Student Association (TSA) and professional associations such as CTEA and ITEA. Finally, in this small study, this over-achieving strategy is exemplified by the fact that most of the teachers had earned at least a master’s degree, several had multiple degrees, and four were pursuing or had earned tertiary degrees, indicating personal drive to achieve.

In response to the third research question — “What steps do the participants believe should be taken to attract more women to technology education studies and careers?” — participants made several suggestions for attracting more females into their chosen profession. First, several of the participants proposed that some type of technology class become mandatory for all students in high school. “Girls do great in Tech Ed (sic) in middle school. But once they go up to the high school, whether because of traditional gender role notions, or just because there are so many new electives, females do not get to experience Tech Ed at a more advanced level” said Eva. This is supported in the literature (Braundy et al., 2000; Monks & Van Boxtel, 1992; Silverman and Pritchard, 1993 & 1996; Wisconsin, 2000).

Two participants responded that “the hiring of new staff” who are more enlightened will create a safer and more welcoming environment for girls and young women. One female teacher noted that the gender ratio of her students had become more equitable every year since she began working at her school although “manufacturing classes still drew more male students.”

The three study members who attended the focus group meeting wanted to add their unanimous belief that guidance counselors wield a great influence on the course selection of girls/young women upon entering high school. This group of participants suggested that school counselors should be better informed regarding technology education and should be educated regarding the wide range of STEM activities and careers that are available for girls.

Another respondent touched on the budgetary issues and the lack of national support for Career and Technology Education in the national "No Child Left Behind" legislation. "I think that the most important issues facing technology education are opposing and avoiding cutbacks to our profession." Another concurs, "We need to actively lobby our local, state, and national legislators in order to ensure that our profession is not one budget cut away from elimination."

Yet another responded that the "way to strengthen our profession is to look to… reflect the diversity of [our student and community] populations in our own classrooms and enthusiastically mentor students and colleagues who show an interest in technology education or related careers." Further, she states that, "If we start bringing in guest speakers, resources, and materials that represent the different genders and cultures of our students they will be able to form better pictures in their minds about what they can do in technology education and more. Then, we need to encourage our students and colleagues to explore their options involving a technology education career. We need to offer more professional development opportunities for lateral entry professionals, scholarships for people interested in technology education, and a mentoring network that targets numerous populations."

Another's suggestions included: "…[W]e must ally ourselves with other teaching organizations, such as the Association for Educational Computing and Technology, the Association for Career and Technical Education, the National Science Teachers Association, the National Education Association, and the National Council of Teachers of Mathematics" in order to collaborate to educate the "whole student."

Implications

This study sheds new light on the extent to which cultural beliefs, institutional policy, and education, the media, and mentoring/role modeling bar or encourage girls/young women/women to pursue studies in technology education and perhaps other STEM fields. The study showed that these factors are important and they all contribute to the worldview of women that supports or constrains their career choices. The findings from this study indicate that girls need positive role models in life and in school. In early childhood/childhood, all but one of these participants had a very positive relationship with an adult male, either a father or a grandfather, who guided them through experiences that supported their interests in these activities. These positive experiences started at an early age and continued throughout their lives. The essential finding of this study seems contrary to much of the recent STEM related literature. A good deal of the literature (Braundy, et al., 1999; Grant & Ward, 1992; Kandaswamy, 2003; NSF, 2003) suggests that children develop self-image best through same-gender role modeling. However, these respondents suggested that girls benefit from positive male role models who support the girls' explorations in hands-on, problem solving activities early in their youth and continuing throughout their youth, including their middle and high school experiences.

The Developmental Process Model explains that the building blocks to attract more girls/young women/women are derived from positive connections with others, development of confidence due to success and praise, and the bonding or connecting with adult role models who provide positive emotional ties. At the focus group meeting, Fiona said with a sigh, "What a relief…a load off women's shoulders to finally hear that men (sic) are part of role modeling for young women. All I've ever heard is that women need to draw more girls into Tech Ed." The Developmental Process Model suggests that everyone, especially males, need to connect to the next generation and guide our youth in a positive manner.

This study also found that these participants felt good about math and/or science early in their educational careers. Silverman and Pritchard (1996), who found that "beliefs about math and science were also an important factor in the decision of girls … to take advanced courses or pursue such subjects as careers," support this finding. This study indicates that to get more girls to consider STEM areas of study, including technology education, and possible careers in these fields, parents and teachers, especially fathers and male teachers, need to develop and display an inclusive belief system, knowledge of pedagogy, and familiarity with new techniques and technologies. The findings from this study point to a number of specific activities that would be helpful to prepare female students for a technological future. Recommendations include:

1. Provide information on diversity, accessibility, and learning styles (Gardner, 1993, 2000) to make families and faculty aware of the nature of girls' learning needs and, as Fiona said, provide "resources, and materials that represent the different genders' [interests so girls] will be able to form better pictures in their minds about what they can do in technology education."
2. Provide educational experiences to boys and men that express and impress how important positive, caring, role modeling is to all children's (*girls and boys*) [authors' emphasis] development. Most of this study's participants had positive relationships with their fathers, grandfathers, and male teachers. These women believe that they proceeded into these STEM related careers because their male role models and teachers encouraged and supported their quests.
3. Create opportunities for elementary teachers to become more familiar and comfortable with the use of math, technology, and science in the classroom, especially emphasizing that all human beings, not just males, can be successful in these areas. Manning & Manning (1991) wrote that American elementary schools create many students who are not comfortable with math and science because the women who teach elementary students have been "conditioned by society and their

teachers to dislike" science and math or to feel they cannot do science or math well. The literature (Sanders, 2005; Sadker and Sadker, 1994) suggests that young girls, who look to the teachers as role models, feel inadequate to pursue science, math, and related topics due to their teachers' implied message that these topics are not for females. Adding to the dilemma is the fact that over 80 % of elementary school teachers are women (NEA, 2003b).

4. Incorporate technology education and engineering principles early in the curriculum to expose girls and boys to real applications for math, science, and technology. The participants in this study indicated that they had positive or very positive experiences with fathers and grandfathers while using tools and technology in their early childhood experiences. However, more than 25 million children in America (Children's Defense Fund, 1998) are in single parent households with little or no connection to their fathers or other male relatives. Therefore the responsibility of the public school system to provide male modeling and support is increased.
5. Encourage more males to enter early childhood education so that positive male role models are available to young children in balance with the positive female role models that already exist. This balance could be considered a national emergency (see #4 above).

In terms of public policy, the findings from this study raise the question "What is the national commitment to improving the equity in technology education and STEM education?" Administrators and legislators should develop new ways of thinking about making STEM education and fields more relevant and interesting to girls and young women throughout their educational careers. First, math and science should be made more accessible for girls in all grades. Further inclusion of technology education and STEM in the primary school curriculum, meaning both the inclusion of better science and math learning experiences as well as technology education, is needed. Second, re-prioritizing financial resources to better assure inclusive pedagogy would help to provide materials, equipment, and technology needed to increase gender equity in STEM education. It is important to restructure budgets to include specific allocations for technology education pedagogy. A national effort in this regard would address one of the participant's (Anna) comments that "I think that the most important issues facing technology education are opposing and avoiding cutbacks to our profession." Another participant, Jan, concurs, "We need to actively lobby our local, state, and national legislators in order to ensure that our profession is not one budget cut away from elimination."

There are also implications for further research. This small qualitative case study is limited by the "chain" or "snowball" sampling technique simply because there is no clearinghouse of data on female technology education professionals. A quantitative study that could randomly sample a significant cross section of the female technology education teachers would have more significance in strategic goal discussions in education and possibly have an impact on national educational policy formation. As a precursor for such a study, demographic information needs to be collected to describe teachers in regard to age, ethnicity, gender, and topics taught. This would provide a demographic baseline of the profession, with gender and ethnicity being particularly important.

Once a baseline study is completed then professionals in the field can begin to address the difficult questions about technology education. For example, do technology education teachers think about and respond differently to female students? Do instructional strategies change for female students so that they are encouraged or discouraged? The qualitative case study reported herein was conducted as a very small, focused, research project. Expanded research involving a larger number of participants that accurately represent a cross-section of female technology education teachers would give these results more generalizability.

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Gender Preferences in Technology Student Association Competitions

Charles R. Mitts

Significantly fewer female students are enrolling in technology education courses compared with males. According to Sanders (2001), female enrollment in the U.S. was determined to be almost half (46.2%) technology education enrollment in middle school, but fell dramatically in high school to less than one-fifth (17.7%). Data from the North Carolina Department of Public Instruction (2004-2005) showed that only 8.6% of females who enrolled in Exploring Technology Systems in Middle School elected to take the freshmen level technology education course, Fundamentals of Technology (see Table 1).

Background

Society is increasingly dominated by rapidly evolving systems of technology. The goal of technology education, as an academic component of public education, is to ensure that students become “technologically literate” members of society who are able to understand, access, use, manage, and control these technological systems. The course content of technology education is prescribed in standards published in 2000 by the International Technology Education Association (Scott & Sarkees-Wircenski, 2004).

Philosophical Basis of Male Gender Bias

There has been a move to refer to gender differences in the classroom as inequities rather than biases, but bias remains a more accurate word for the technology education classroom, which remains a place for males. This circumstance has deep roots in the development and impact of Western philosophy concerning differences between males and females (Lloyd, 1993).

Impacts of Male Bias on Female Social Status

The 19th century saw the birth of women’s struggles for social reform in the U.S. The status of women in the U.S. was still separate and inferior to men. Their roles were limited to the home. Reforms of the period were aimed at

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freedom in how one dressed as well as and equal rights in marriage, employment, and voting. It wasn't until the middle of the century that higher educational opportunities became available for women (Berg, 1984). In the 20th century, it was not until 1922 that women's right to vote was upheld by the U.S. Supreme Court. As we continue into the 21st century, the status of women is still a major concern. More women are likely to be left to raise children alone, be poor (Ohio State University Extension Service, n. d.), and become victims of violence (Family Violence Prevention Fund, 2007).

Impact of Male Bias on Technology Education

There are too few technology education teachers (Ndahi 2003, Sanders 2001) in general. The fact that there are too few female technology education teachers is partially due to the consequence of an historic split of vocational education into male dominated industrial arts and female dominated home economics, which occurred in the early 20th century at the culmination of a successful campaign to secure Federal funding for vocational education through the passage of the Smith-Hughes Act in 1917 (Scott, 2004). This split signified a victory for those in the profession who believed that the focus of industrial arts should be on skills development, as opposed to the views of some women who had represented a broader and more inclusive perspective (Zuga, 1996).

In the beginning, industrial arts education included significant numbers of women who were influenced by the philosophy of John Dewey. These early programs were seen as part of a liberal education and were intended for all students, girls as well as boys (Zuga, 1996). The emergence of technology education in the 1980s and the subsequent adoption of the *Standards for Technological Literacy: Content for the Study of Technology* (ITEA 2000) represent a return to our profession's general education philosophy. With the ever increasing amount of technological development, "teaching concepts versus specific technology allows technology education to provide the technologically literate citizens needed to survive and advance in a technological society" (Hoepfl, 2003, p.61).

The Technology Student Association is potentially the best vehicle for attracting females into technology education, because it allows female students to work together within the field and to pursue projects of interest to them. However, the emphasis in Technology Student Association chapters on competitive events may represent an obstacle to attracting females into our program because research suggests that females find competitive events less appealing than do males (Weber and Custer, 2005). This research study also suggests that many of the topics in the *Standards for Technological Literacy* are inherently less interesting to female students.

As reported in Table 1, significantly fewer female students are enrolling in technology education courses in North Carolina compared to males. North Carolina is the focus of this study.

Table 1
Students Enrolled in North Carolina Technology Education Courses 2004-2005

Course	Males	Females	Ratio
Exploring Technology Systems	30258	18446	1.64:1
Fundamentals of Technology	11107	1594	6.97:1
Manufacturing Systems	853	27	31.59:1
Principles of Technology I	1943	547	3.55:1
Principles of Technology II	395	49	8.06:1

Note: The researcher selected these courses because they were offered at the Lincoln County High School where he taught during the 2004-2005 school year.

Achieving Gender Equity in Technology Education

Attracting and keeping females in the technology education classroom will require fundamental changes in both course content and instructional practices (Zuga, 1999). Kleinfield (1999) cites research that reveals major differences in career preferences between males and females. According to this report, women prefer fields that involve people and living things, such as law, medicine, and the biological sciences, while men prefer fields which deal with the inanimate, such as physics, chemistry, mathematics, computer science, and engineering.

The issue is not whether or not females can do the work. Females are just as likely as males to use computers, more likely to participate in non-athletic activities after school, have higher educational aspirations than males, and are more likely than males to immediately enroll in college. Women comprise the majority of students in undergraduate and graduate programs, and are more likely to persist and attain degrees (Freeman, 2004). The problem is not that women are being excluded from engineering fields, they are simply not choosing courses of study that lead to careers in engineering. Simply unlocking the doors to these fields and encouraging women to walk through them may not be working for a variety of reasons.

It is a natural response to the discovery that women have been unfairly excluded from educational arenas and occupational fields to now affirm the value of having female contributions within these areas as part of the process of ending sexual discrimination. However, the situation is complicated by the fact that what women believe it means to be a woman has developed over the centuries within the context of and by relationship to a male defined norm (Lloyd, 1993, p.104).

Throughout industry there exists a large disparity between the number of men and women employed in occupations dependent upon a knowledge of science, math, and physics. In 1994 a group calling itself *Women in Aviation International* (WAI) was established to promote opportunities in aviation for women. Twenty-three percent of its 15,000+ members are students. WAI claims that currently only 6% of the 700,000 active pilots in the U.S. are women, with just slightly more than 2% being ATP (Airline Training Program) rated. Women are employed in just over 2% of the 540,000 non-pilot jobs in the aviation industry (WAI, 2006). Technology education may help students identify career interests and aptitudes. Current percentages of women in technical occupations are listed in Table 2 (Bureau of Labor Statistics, 2005).

Table 2
Percent of Women in Technical Occupations 2005

Occupation	Percent
Construction manager	6.4
Engineering manager	5.9
Aerospace engineer	11.3
Chemical engineer	15.8
Civil engineer	11.7
Computer hardware engineer	12.7
Electrical and electronics engineers	7.9
Mechanical engineers	5.8

Strategies for Recruiting Females to Science and Technology Fields

A study funded by the National Science Foundation (Whitten, 2003) identified a number of things that can be done to create a warm and female-friendly culture in a university physics program. For female faculty, this study recommends family-friendly policies that allow women to balance work and the responsibilities of children and/or elderly relatives. It also emphasizes the importance of communicating and practicing an open-door policy between faculty and first year students. It encourages the creation of an inclusive environment where team work is encouraged. The study further advises to begin recruitment early by having faculty judge high school science fairs and participate in summer bridge programs, create web sites which emphasize the participation of women, and maintain a network of alumni who can return for career panels and give seminars. The study found a strong correlation between females on the faculty and the number of women who leave academia to become scientists in the private sector and in government.

One of the solutions being considered in science courses at the high school level are single-sex classes. Although anecdotal evidence supports that there are benefits from single sex classes, a 1998 report challenges this evidence. It stated that co-education works just as well as single-sex classes and schools when the following elements are present (Sharpe, 2000):

- small classes and schools
- equitable instructional practices
- focused academic curriculum

According to the research done by Weber and Custer (2005) on the preferences of females in technology education, females prefer activities that focus on design and communication. “This is particularly true when the *design* activities include a focus on problem solving or socially relevant issues” (Weber, 2005, p. 60). One of the main purposes of the Weber-Custer study was to identify what types of activities are most preferred by females and males. Their study divided 56 activities into four categories: Design, Make, Utilize, and Assess. Student participants were ask to rate these activities according to their interest level using a five category, Likert-type scale with options ranging from *Very Interesting* to *Not Interesting* at all. The research findings revealed no significant difference between males and females for activities in the Make and Assess categories. However, the research survey did find differences between males and females for activity items in the Design and Utilize categories. Looking at the composite results of all items in the Design category revealed a statistically significant level of variance. However, the composite survey results were not statistically significant for the Utilize category.

Of the 56 activities considered, females preferred those whose focus was on design or communication and that are socially relevant. The top five items selected were:

1. Use a software-editing program to edit a music video.
2. Use a computer software program to design a CD cover.
3. Design a model of an amusement park.
4. Design a school mascot image to print on t-shirts.
5. Design a “theme” restaurant in an existing building.

In contrast to the choices made by females, males picked the following five items as their top choices from the same list of 56 activities:

1. Build a rocket
2. Construct an electric vehicle that moves on a magnetic track
3. Perform simple car maintenance tasks on a car engine
4. Program a robotic arm
5. Design a model airplane that will glide the greatest distance

Method

Gender Preferences among TSA Competitive Events

Based on the Weber-Custer research study, , the researcher chose 14 out of the 33 activities described in the 2005-2006 Official TSA Competitive Events Guide for High School Technology Activities that focused on design and communication. The researcher made no judgment concerning the social significance of the activities chosen. They are:

1. Architectural Model
2. Chapter Team
3. Computer-Aided Design 2D Architectural
4. Computer-Aided Design Animation, Architectural
5. Cyberspace Pursuit
6. Extemporaneous Presentation
7. Film Technology
8. Imaging Technology
9. Prepared Presentation

10. Medical Technology
11. Promotional Graphics
12. Technical Sketching and Application
13. Technological Systems
14. Technology Bowl

The researcher determined the “Event Type Category” by making a judgment based upon the description of each event contained in *The Official TSA Competitive Events Guide* for both Middle and High School levels. From the description of the 64 events included, the researcher developed the following event types categories: Designing and/or Communication (26), Utilizing (26), Design and Utilize (1), Research and Utilize (1), Research and Presentation (2), Writing and Communication (2), Research and Writing (4), Technology Knowledge (1), and Research and Display (1). A Prediction column was included on the coding sheets to indicate the expected gender preference for each event. In addition, in the TSA Chapter Kit are four categories of activities that include ideas that the Weber-Custer study findings suggest should appeal to female students. These categories are: Scholastic/Educational, Professional Leadership, Civic and Community, and Social (Technology Student Association, 2005).

Research Design

The results of the Weber-Custer research pointed to clear differences in gender preferences based upon distinct categories of activities. The validity of the Weber-Custer study and the reliability of the categories in the study as a predictor of gender preferences were tested by examining the gender choices at TSA competitive events. In addition, the criteria in the Weber-Custer study where used to categorize each event by type. Frequency counts of male and female activity choices at TSA competitions formed nominal data sets. Chi-square statistical analysis was used to determine whether a pattern or characteristic is common to a particular event category (Gray, 2005).

Participants and Instruments

This research study included the records of all male and female participants in all the middle and high school competitive events at the North Carolina State TSA Conferences in 2005 and 2006. Datasheets were used to record the data collected. One set of datasheets listed the 31 middle school events and the second set listed the 33 high school events. The data sheets were separated by contest year. Each event sheet included the name of the event, the school name, a list of participants, and the total number of students participating in each event. Most students participated in multiple events. The total number of students participating had to be determined by compiling master lists and then eliminating multiple names. Student gender was also determined by examination of names. Names for which the gender was not certain were tabulated separately. This process yielded 246 males, 187 females, and 113 students of undetermined gender for middles school events and 244 males, 115 females, and 103 students of undetermined gender at the high school level.

Data Analysis

Chi-square (X^2) analysis was used to determine if males and females were biased in their choice of events, if they preferred individual versus team events, and whether or not their selection of types of events was statistically significant. In each of these categories, the number of males and females who would be expected (f_e) in each category, if no bias exists, was compared to the actual number observed (f_o), using the formula $X^2 = \sum [(f_o - f_e)^2/ f_e]$ (Gay 2006, p. 372). Calculations were performed using Excel data table and formula functions. The value X^2 was then compared to a number from a Chi-square distribution table (Gay 2006, p.576.). Degrees of freedom were found by the formula df = C-1 where C equals the number of items in each category, such as "Event Type." An alpha level of .05 was chosen for the study. Thus, selecting "p = .05" on the X^2 distribution table means that statistical significance is 95% certain. The value X^2 is considered statistically significant if it was greater than the value listed in the X^2 distribution table.

Results

Middle School

Out of 31 events from which to choose, the *Dragster Design Challenge* was the only one to have a statistically significant bias for males (45.754 > 43.773). The numbers for males contrast with an X^2 value of only 0.176 for females, against the X^2 distribution value of 43.773. In addition to analysis by choice of event, chi-square analysis revealed a significant difference in three other categories: Individual entrant, Team entrant, and Event Type. In the individual entrant category there was a significant difference for males in two events: *Dragster Design Challenge* and *Flight Challenge.* Similarly, the choice of two events by females was statistically significant for *Digital Photography* and *Graphic Design Challenge*. In the "Team" event type category there was a significant difference for males in four events and females in six events. For "Event Type" females preferred eight events by a statistically significant margin and all of them were "Design and/or Communication" type activities. Males preferred five events, all "Utilizing" type events. The *Technology Bowl Challenge*, which the researcher designated as a "Technology Knowledge," non-utilizing type event, showed a male significant difference in both the "Team" and "Event Type" categories. Table 3 shows the Technology Student Association competitions preferred by males, and Table 4 shows those preferred by females.

Table 3
Statistically Significant Differences in Male Preferences at NC TSA 2005-2006 Middle School Competitions

Event Name	**Event Category**	**Chi-Square** **$X^2(df, N), p < .05$**	**Distribution of X^2**	**% Male/Female**	**Gender Prediction**
Dragster Design Challenge	Combined Individual Utilizing	$X^2(30, 246) = 45.754$ $X^2(13, 246) = 97.692$ $X^2(11, 246) = 29.280$	43.773 22.362 19.675	85.5/ 14.5	M
Flight Challenge	Individual Utilizing	$X^2(13, 246) = 42.823$ $X^2(11, 246) = 19.675$	22.362 19.675	83.3/ 16.7	M
Problem Solving	Team Utilizing	$X^2(16, 246) = 137.037$ $X^2(11, 246) = 72.305$	26.296 19.675	76.6/ 23.4	M
Structural Challenge	Team Utilizing	$X^2(16, 246) = 64.415$ $X^2(11, 246) = 29.280$	26.296 19.675	63.4/ 36.6	M
Technology Bowl Challenge	Team Tech.-Know.	$X^2(16, 246) = 35.080$ $X^2(18, 246) = 44.664$	26.296 28.869	58.7/ 41.3	N
Manu-facturing Challenge	Team	$X^2(16, 246) = 26.359$	26.296	73.9/ 26.1	M

Nine competitive events showed a statistically significant difference: five by males, two by females, and two events, *Film Technology* and *Technology Bowl*, by both males and females. Only one event, *Dragster Design*, registered a statistically significant preference for males, 79.184 > 24.996 when chi-square was used to analyze data in the “Individual” entrant category. The X^2 value for females in this category was 0.922. Team events were preferred by males in three cases, by females in two, and by both males and females in two. Under the category “Event Type,” males chose “Utilizing” type events in three cases, and a non-utilizing type event, *Cyberspace Pursuit*, in one. Females selected non-utilizing type events by statistically significant margins twice; both were designated as “Designing and/or Communication” type events. The events with a significant difference for males are listed in Table 5 and for females in Table 6.

Table 4.
Statistically Significant Differences in Female Preferences at NC TSA 2005-2006 Middle School Event Competitions

Event Name	**Event Category**	**Chi-Square** X^2(***df***, ***N***), ***p***<.05	**Distribution of** X^2	**% Male/Female**	**Gender Prediction**
Challenging Technology Issues	Team Design/ Communication	$X^2(16, 187) = 40.091$ $X^2(18, 187) = 49.905$	26.296, 28.869	33.3/ 66.7	F
Chapter Team	Team Design/ Communication	$X^2(16, 187) = 36.364$ $X^2(18, 187) = 45.503$	26.296, 28.869	35.4/ 64.6	F
Cyberspace Pursuit	Team Design/ Communication	$X^2(16, 187) = 61.455$ $X^2(18, 187) = 74.966$	26.296, 28.869	40.3/ 59.7	F
Digital Photography Challenge	Individual Design/ Communication	$X^2(13, 187) = 57.183$ $X^2(18, 187) = 98.673$	22.362, 28.869	30.5/ 69.5	F
Environmental Challenge	Team Design/ Communication	$X^2(16, 187) = 29.455$ $X^2(18, 187) = 37.307$	26.296, 28.869	38.3/ 61.7	F
Leadership Challenge	Team Writing & Commun.	$X^2(16, 187) = 52.364$ $X^2(18, 187) = 64.332$	26.296, 28.869	30.0/ 70.0	N
Graphic Design Challenge	Design/ Communication	$X^2(18, 187) = 45.503$	28.869	27.9/ 72.1	F
Video Challenge	Team Design/ Communication	$X^2(16, 187) = 29.455$ $X^2(18, 187) = 37.307$	26.296 28.869	42.0/ 58.0	F

Table 5
Statistically Significant Differences in Male Preferences at NC TSA 2005-2006 High School Event Competitions

Event Name	**Event Category**	**Chi-Square** **X^2(*df*, *N*), *p*<.05**	**Distribution of X^2**	**% Male/Female**	**Gender Prediction**
Cyberspace Pursuit	Combined Team	$X^2(32, 244) = 134.940$ $X^2(17, 244) = 47.801$ $X^2(18, 244) = 53.628$	46.194 27.587 28.869	83.0/ 17.0	F
Dragster Design	Combined Individual Utilizing	$X^2(32, 244) = 245.238$ $X^2(15, 244) = 79.184$ $X^2(13, 244) = 60.872$	46.194 24.996 23.685	87.7/ 12.3	M
Film Technology	Combined Team Design/ Communication	$X^2(32, 244) = 171.265$ $X^2(17, 244) = 64.008$ $X^2(18, 244) = 71.253$	46.194 27.587 28.869	68.3/ 31.7	F
Flight Endurance	Combined	$X^2(32, 244) = 69.022$	46.194	90.9/ 9.1	M
Structural Engineering	Combined Team Utilizing	$X^2(32, 244) = 280.995$ $X^2(17, 244) = 114.856$ $X^2(13, 244) = 72.601$	46.194 27.587 23.685	79.1/ 20.9	M
Technology Bowl (Written & Oral)	Combined Team Design/ Communication	$X^2(32, 244) = 635.940$ $X^2(17, 244) = 287.823$ $X^2(18, 244) = 312.050$	46.194 27.587 28.869	78.3/ 21.7	F
Technology Problem Solving	Combined Team Utilizing	$X^2(32, 244) = 496.265$ $X^2(17, 244) = 218.805$ $X^2(13, 244) = 146.741$	46.194 27.587 23.685	85.0/ 15.0	M

Table 6

Statistically Significant Differences in Female Preferences at NC TSA 2005-2006 High School Event Competitions

Event Name	**Event Category**	**Chi-Square** $X^2(df, N), p<.05$	**Distribution of** X^2	**% Male/Female**	**Gender Prediction**
Chapter Team (Written and Oral)	Combined Team Design and/or Communication	$X^2(32, 115) = 144.643$ $X^2(17, 115) = 60.180$ $X^2(18, 115) = 65.786$	46.194 27.587 28.869	42.2/ 57.8	F
Film Technology	Combined Team Design and/or Communication	$X^2(32, 115) = 77.786$ $X^2(17, 115) = 28.988$ $X^2(18, 115) = 32.166$	46.194 27.587 28.869	68.3/ 31.7	F
Medical Technology	Combined Team Design and/or Communication	$X^2(32, 115) = 340.071$ $X^2(17, 115) = 156.368$ $X^2(18, 115) = 168.728$	46.194 27.587 28.869	35.6/ 64.4	F
Technology Bowl	Combined Team Design and/or Communication	$X^2(32, 115) = 87.500$ $X^2(17, 115) = 33.404$ $X^2(18, 115) = 36.943$	46.194 27.587 28.869	78.3/ 21.7	F

Conclusions

Male and female TSA members differ in their preferences for types of competitive event activities. These different preferences are clearly reflected in data Tables 3-6, which list all events for which statistically significant differences were found. Males clearly have a strong preference for utilizing type activities such as *Dragster Design* (7 out of 9 events), while females have an even stronger preference for non-utilizing, design and/or communication type events (10 out of 10), such as *Medical Technology.* These results are consistent with the findings in the Weber-Custer (2005) study. Using the gender preference criteria in the Weber-Custer report, the researcher made a correct prediction of gender preference for TSA competitive event activities in 20 out of 21 cases (95%) for which statistically significant results were found. In addition, the data clearly suggest that both males and females prefer team activities; by a margin of 77%. Just as in the Weber-Custer research study, the researcher found that the female preference for design and/or communication type activities was statistically more pronounced than the male preference for utilizing type activities. *Film Technology* and *Technology Bowl,* appealed to both males and females by statistically significant margins.

Discussion

This study clearly reveals that strong gender preferences motivated male and female choices of activities at the 2005 and 2006 middle and high school TSA State Conferences in North Carolina. Males preferred activities where the creation of an artifact, such as a dragster, was an end in itself. On the other hand, females preferred activities such as *Medical Technology* that had some social significance. The roots of this difference in gender choices can be found in the philosophical tradition of Western culture: abstract thought was held to be an exclusively male province while females were restricted to those activities in and around the home. This tradition in Western culture is reflected in the history of vocational education in the U.S. by its split into industrial arts for males, and home economics for females.

The emphasis of technology education on “hands-on,” utilizing type lab activities, such as such as making dragsters, may be a major reason for technology education’s failure to adequately attract and keep female students in programs. Table 1 documents a decline of 16,852 female students between middle school and high school who enrolled in technology education in North Carolina, a decline of 91.4%. In the North Carolina Technology Student Association data for the 2005 and 2006 state conferences, female participants declined by 38.5% between middle school and high school. This study suggests that, in order to attract and keep female students, an emphasis in technology education programs should be placed on activities that appeal to both genders. These kinds of activities are already incorporated into TSA specifications and programs of study.

The Technology Student Association should consider collecting and analyzing gender-based data from competitive activities from all of its state and national conferences. The technology education curricula should be analyzed to determine the extent to which “Utilizing” type activities, that appeal primarily to females, are incorporated compared to “Design and/or Communication” activities, that appeal primarily to males. Technology education course updates and revisions in North Carolina and across the nation should be based on knowledge of gender preferences and interests, with the goal of significantly improving the number of female students who are attracted to, and remain in, technology education programs, including the pursuit of careers as technology education teachers.

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Editorial

Are We Compromising Safety in the Preparation of Technology Education Teachers?

W. J. Haynie, III

As our curriculum has evolved over the 40 plus years that I have been invested in technology education (formerly industrial arts education), I have observed with interest the various changes that have occurred. I entered industrial arts (IA) as a junior high school student in a mixed woods and metals class in the early 1960’s. My school experience was almost entirely an unhappy one save for my “shop” class. Yes, even though leaders in the field of IA had already begun encouraging the abandonment of the word “shop” in favor of the more academic sounding “laboratory,” we kids called it “shop.” And, we knew what the class was about too. From our perspective, shop was about “makin’ things.” In hindsight, as a professor with a Ph.D., I now know that the goals of my teachers and the classes that they taught little resembled “makin’ things in shop”—rather, the projects and other activities were both the sugar to make the medicine go down and the learning activities that transmitted information and skills more effectively than mere lectures and reading. I still have the chessboard, candy dish, lathe turned bowl, carved salad servers, model cannon, tool tray, and (the ubiquitous) lamp that I made in my two junior high shop classes. What’s more important, I have a great deal of knowledge and skills that I can apply to many problem solving situations which neither I nor my teachers could have envisioned back then. And I know how to be safe in a lab and safely use equipment. In high school I took one year of drafting and three additional years of Woodshop (by that name). The solid cherry drop-lid desk (secretary) that I built in advanced woods was the one thing that kept me from dropping out of high school and eventually led me to both a scholarship and a career as an alternative to the petty criminal track that I had already begun to enter. When I accepted the scholarship to become a shop teacher and entered the nearby college to receive the education, I was exposed to new ideas. The professors

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there didn't call the instructional facilities shops—they were labs. The projects were learning activities or products. There was much more emphasis on why a student might build a jewelry box than on the quality of the joint in the tiny drawer that was part of it. My high school shop was well equipped, but this college lab in which I was to be prepared as a teacher was pitiful, at best. There were even some fools already talking about how we should abandon woodshop all together! And this was in the late 1960's.

On the other side of the argument, there were some diehards who maintained that teacher preparation students of that era were substandard in technical skills; that they didn't have the technical knowledge or skills to be safe in producing projects themselves and therefore most certainly could not lead school children in such endeavors. The 1960's progressives pressed for incorporation of other materials such as plastics, leather, ceramics, etc. in addition to the tried and true woods and metals. New topics were advanced such as surveying and thermoforming, along with mass production techniques replacing individual projects and general labs instead of unit shops. The traditionalists maintained that we should continue to do what we always had done and do it well—we knew who we were and should not be ashamed of it. But, despite the wide gulf of differences, both the progressives and the traditionalists did agree about one thing. That is, safety was one of the most important things for secondary school students to learn and it was foremost in all of the lab or shop classes in the education of IA teachers. Safety was paramount and in the center of everything we did.

The early 70s found me teaching one of the new *World of Construction* courses from the Industrial Arts Curriculum Project. I had mixed emotions about it. On the one hand, I liked some aspects of it very much but on the other I feared that there was something missing when the highest level of finish a student learned to apply was latex paint and that the creative spirit of the classes I loved so much in high school was gone. I had to find answers for my students who asked why they had to work in groups to build a wall section and then disassemble it instead of getting to build a gun rack like their older brother did the year before. I knew in my heart that something more than simply "shop" was going on, but I was not sure whether it was better or not. Nonetheless, safety was paramount! Students learned and demonstrated safety in every activity.

As I advanced in my profession, becoming a successful IA teacher and going on for graduate work, I not only observed the debate about the value of developing skills in the use of tools versus conceptual content, but I eventually became embroiled in it myself. Which side did I take? Up until about 1982 I was on the progressive side, pushing for a broader understanding of technology with less emphasis on vocational type skills, along with more concern that students understood "the big picture." My cognitivistic viewpoint led me to seek connections between topics in IA and the academic subjects. My belief that students preparing for tomorrow needed to understand and respond to the challenges and impacts of technology impelled me to weigh "how to do" less heavily than "why." Moreover my concern that IA be infused more clearly into the general school curriculum and thereby cutting our vocational apron strings made me seek ways and opportunities to teach content from all school subjects via our activity-centered approach. The "standards" developed by many other disciplines were in tune with this thinking as well. Slowly, however, I began to have some fears about the new direction our curriculum was taking.

The early 1980's found me in my new role as teacher educator rather than teacher. I had my first opportunities to go out into the schools and watch fledgling teachers test out their developing wings. The institution at which I taught had wholeheartedly embraced the progressive thought—there was a manufacturing class, but no woods or metals class pre-requisites. There was communications, but no drafting, electronics, or printing. There was transportation, but no mechanical, engines, or similar classes. And, of course, we had the construction class to round out the entire "designed" world, but students came to the class with no experience with a saw, plane, or nail. The program ran for a couple of years before we produced our first student teachers. A few of those early students were great because they had come into the program from other careers or had completed technical programs at a community college that gave them lots of "shop" skills. However, the ones we had produced from freshmen were absolutely frightening to observe! Their cooperating teachers were aghast at how little these aspiring teachers knew about "how to do" and about safety. The quandary for me was that I still believed in all that was positive about the progressive approach and why it was what the youth of the 80's needed for success in their lives. At the same time, I recognized that the teachers who would lead school programs needed far more skills and knowledge than they were gaining in our progressive college program. We responded by adding a required series of traditional skills classes to our curriculum, including woods, metals, drafting, graphic arts, plastics, electronics, and power-mechanics. The aspiring teachers who had this experience were excellent in all regards. They knew what to teach in the modern era, they knew how to teach, they had skills and understood materials and processes well, and they were safe and knew how to teach safely as well as how to teach safety as a subject of study. Then we became "Technology Education."

As we began to try to live up to our new name, secondary schools and teacher preparation programs across the nation dropped skills classes in favor of systems classes, mimicking what had already failed at my institution. Deans and department heads were elated at the space and money savings and the fresher image of smaller, cleaner labs and fewer hands-on classes. The institution at which I teach today no longer has a woods class or a metals class or a required electronics class. Students never disassemble, inspect, and reassemble a small internal combustion engine. They can lead a class discussion about the impacts and potentials of new technologies, but not a one of them could actually cut a dovetail joint and many of them would not even recognize one! Cluster courses such as Materials and Processes, Imaging Technology, the big four of Manufacturing, Construction, Transportation, and Communication, and a new Emerging Issues course have replaced all of the traditional skills courses. We are well in step with trends in the profession. But are we headed in the right direction? Are we missing anything important?

At the time I began writing this manuscript, I had just returned from the Eastern Regional TECA Conference in Virginia Beach. While watching the Manufacturing competition, I remarked to one of my colleagues, "These students know a lot of technology, but they don't know a darned thing about woodshop!" The students were attempting to make jigs and fixtures and then use them to produce a small football kicking tee using mass production processes. I saw one student trying to cut a 3/8" dowel rod with a ripsaw. The method used to enlarge a hole was to "waller it out" with the drill rather than using an appropriately sized larger drill. Early in the preparation phase one team chose to use a piece of wood with the grain oriented in the wrong direction to make a jig, resulting in a failure on its first trial. It was clear that no one on the team knew any better. Safety was stressed in that everyone wore eye protection and each team marked danger areas with yellow caution tape. They also designed and made guards for jigs and fixtures and posted instructions for their use. Yet it was clearly evident that their knowledge about the woodworking processes was so minimal that they did many operations in unsafe ways.

Immediately after the competition, I received a call on my cell phone from my university informing me that we had had a minor accident in our own lab involving a kickback on a table saw. When I investigated upon my return I realized that the student simply did not have the benefit of enough experience to make a wise and safe decision about how to use the tool. By plunging students directly into problem-solving activities without prior skill development classes, in which they learn to "feel" the power of the tools while performing simple operations, we are very likely endangering them. How many of my colleagues shudder when they look into the production areas of their labs?

Now we find that the new debate in our profession no longer concerns whether or not we are vocational-industrial, emphasizing skill development in the use of tools. Instead there is increasing emphasis on whether we stress engineering design. Courses on either end of this spectrum or anywhere between involve some conventional tools and machines and how they are used to process variety of materials. Though few labs today include the 14" radial arm saw I used in junior high school, there are smaller versions of tools like this in many labs. Some of these tools are high quality, but others are simply not designed for school use are unsafe in a school environment. A table-top size circular saw in one of our labs vibrates so much that I would rather have students use a hand-held saw instead. In conclusion, I feel that the labs of today are less safe, the students of today are inadequately instructed in safety, and the teachers of today simply do not have adequate experience with equipment to lead students safely.

In the March, 2007, issue of *The Technology Teacher* an article appeared by Gunter concerning teaching safety in the modern era. It listed numerous references and resources for information about safety and safety training. One resource that was not listed is *Safety System Design for Technology Education* (3rd Edition) by DeLuca and Haynie (2007). This guidebook examines the four systems courses, points out hidden hazards in our modern labs, and provides activities and forms for students to use to incorporate safety awareness and planning throughout the technology education curriculum. Some colleagues in technology teacher education use this guide as a text or a reference in their laboratory management/safety instruction for pre-service or in-service teachers. Obviously, as one of the authors, I am flattered by their positive comments about the whole-view approach the guide takes on safety education. Nonetheless, I still do not feel that the labs monitored by graduates of the typical technology teacher education program of today can possibly be safe when they receive so very little training in the use of the tools they will be expected to use and to teach about. Despite some personal yearning for "the good ole days" when life was simple and a good woodshop class defined our curriculum, I know that there are more important things to teach that are more appropriate for the majority of students in the nation's public schools. Just the same, I believe that we need to retain some emphasis on skills in our technology teacher education programs so that our graduates will know enough to recognize hazards and be able to maintain safe labs in their schools. Increasingly universities are being expected to prepare teachers within a maximum of 120 semester hours. At the same time, there are increasing expectations for instruction and experiences on diversity, special needs learners, English as a second language, integrated curriculum, and general education. In addition, our programs are expected to align with the National Council for Accreditation of Teacher Education, the Standards for Technological Literacy, No Child Left Behind, and other local and state expectations, along with the increasingly rapid changes in the needs of our students and of society in general. Somehow, we have to assure that our future teachers have adequate skills and knowledge to assure their own safety and the safety of the students they serve in spite of our burgeoning curriculum and the above requirements.

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Miscellany

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