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A Theoretical Framework to Guide the Re-Engineering of Technology Education

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Introduction

Before leaders in technology education are able to identify a theoretical framework upon which a curriculum is to stand, they must first grapple with two opposing views of the purpose of technology education – education for all learners or career/technical education. Dakers (2006) identifies two opposing philosophies that can serve as a framework for technology education, both inspired by ancient Greece, with the works of Descartes and the birth of positivism. Later reappearing in Pascal's writings of the mathematical mind, and finally with Rousseau in the mid 1700s, the theoretical arguments of academic verses vocational were established in education, and thus concluded that the overall purpose of education was to make a man (human being) or a citizen. This dichotomy of views is referenced here to make explicit the underpinnings of a theoretical framework for technology education. The position that the authors take in this dichotomy of views is one that embraces the best of both views by teaching technology education to all students to foster technological literacy while at the same time addressing the needs of a workforce seeking to compete in a global economy. This rationale will be presented throughout the article.

Theoretical Perspectives of Technology Education

Early in the 1990s, in the midst of the name change from industrial arts to technology education, the *Journal of Technology Education* (JTE) published a special theme issue dedicated to examining the state of technology education from different theoretical perspectives (Herschbach, 1992). Herschbach (1992) explains that although curriculum development is not an exact science, there are five basic curriculum patterns generally recognized by curriculum theorists. He identified the five patterns as academic rationalist (separate subjects), technical/utilitarian (competencies), intellectual processes, personal relevance, and social reconstruction.

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The special 1992 issue of JTE featured five authors from the field of technology education (Erekson, Herschbach, Johnson, Petrina, and Zuga) with each author discussing one of the five theoretical frameworks as they relate to technology education. Today, with the field of technology education on the verge of a new shift in focus, it is appropriate to consider a new theoretical perspective for technology education based upon the needs of today's learners and upon new knowledge of teaching and learning obtained through recent research.

The Archway of Meaningful Learning: A Proposed Theoretical Framework

The graphic in Figure 1 illustrates an archway to meaningful learning in technology education. The archway begins with a constructivist approach to learning through a pragmatist or experimental over-arching philosophy as the theoretical foundation upon which all the other learning theories and approaches to learning rest upon. Contextual learning/problem-based instruction and project-based instruction create columns of support for engineering design and systems thinking to provide meaningful learning through a real-world context. Both engineering design and systems thinking become the "drivers" of the learning experience. Systems thinking is above project-based instruction because systems thinking is required for solving open-ended and ill-structured problems that society faces today and such problems are prevalent in engineering design projects. At the top of this archway of meaningful learning is *student learning,* forming the keystone of the arch, at the heart of why we need to teach from a

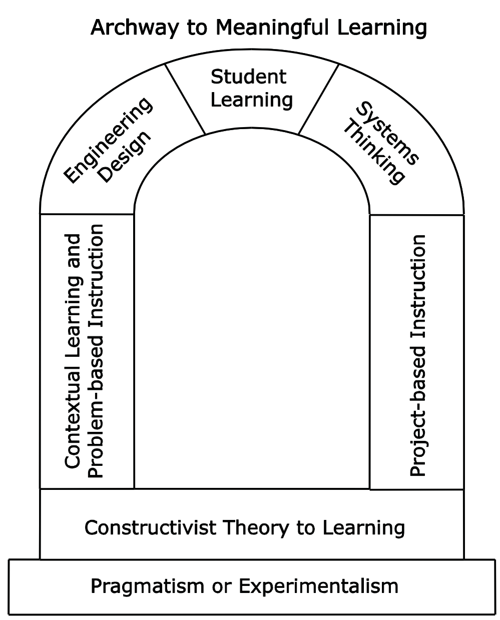

Figure 1. The Archway to Meaningful Learning in Technology Education.

constructivist approach. Student learning is supported by all other "building blocks." Throughout the rest of this article, the authors will present their rationale for why technology education should adopt this theoretical framework and describe the benefits of adopting this approach to technology education.

Pragmatism or Experimentalism

The conceptual underpinning of the proposed philosophy of technology education is founded on the ideas supported by the works of Woodward (1894), Dewey (1916), and Warner, Gray, Gekbracht, Gilbert, Lisack, Kleintjes, et al. (1947), each of whom proposed that technology education is for all learners. That is, they believed that technology education should equip the learner with necessary knowledge, skills, and abilities in the context of technology, and to live, function, and work in today's technological society. Furthermore, the authors embrace a pragmatist view, also known as experimentalism, which has been promoted through the progressive and reconstruction movement of the late 19th and early 20th centuries. Pragmatism supports the notion that knowledge is gained through problem solving, it places great emphasis on critical thinking and reasoning, and it seeks to solve the world's problems with an open mind (Scott & Sarkees-Wircenski, 2001). Moreover, the authors support technology education with an engineering design focus as a vehicle for fostering technological literacy while simultaneously developing the skills needed to work in a global economy. A review of some of the recent commissioned reports on preparing a workforce ready to compete in a global economy uncovers lists of necessary job skills that are also technological literacy skills (Committee on Prospering in the Global Economy of the 21st Century, 2007; National Center on Education and the Economy, 2006). Developing technological literacy goes far beyond providing vocational skills and making students "technologically savvy"; it is focused on understanding how technology has changed our world and how we live in it. Michael (2006, p. 56) adds that technology education should prepare young people to cope in a rapidly changing technological world; enable them to think and intervene creatively to improve that world; develop skills required to participate responsibly in home, school and community life (citizenship); help them become discriminating consumers and users of products; help them become autonomous, creative problem-solvers; …encourage the ability to consider critically the use, effect, and value dimensions of design and technology (technological awareness or literacy).

It is our belief that technology education, with a focus on engineering design, is as beneficial for students who want to become attorneys, physicians, accountants, business managers, clergy, and writers as it is for future engineers. One very important component of each of these occupations is that people working within them function in an environment comprised of ill-structured problems. Educators agree that problem-solving skills are critical for a successful person in today's world; however, it is important to note that ill-structured problem-solving helps to better prepare students to cope with real-world problems (Jonassen, 1997). Well-structured problems are constrained and usually have one correct answer, while ill-structured problems are not constrained and have multiple possible solution trajectories and final solutions (Jonassen, 1997). Whether a student selects the field of law, business, or medicine to study, they will encounter many ill-structured problems that are domain or context dependent (Bransford, 1994). Engineers have developed an excellent systematic approach to ill-structured problems known as the engineering design process. Engineers have an excellent record of taking a complex and often chaotic problem and using the engineering design process to consider multiple perspectives, and oftentimes break the problem down into manageable sub-problems that can be solved with a set of possible solutions. The skill of managing chaotic and ill-structured problems is useful to all occupations.

A Constructivist Approach to Engineering Design and Systems Thinking

Dewey captured the general philosophy of a constructivist view of learning when he made the statement:

> We are given to associating creative mind with persons regarded as rare and unique, like geniuses. But every individual is in his own way unique. Each one experiences life from a different angle than anybody else, and consequently has something distinctive to give others if he can turn his experiences into ideas and pass them on to others (1930, p. 3).

Jacobson and Wilensky (2006) suggest that young learners can handle complex systems thinking even at the middle school level. They suggest using a constructivist approach to learning, a philosophy of learning based upon foundational works of Dewey (1930), Piaget (1985), and Vygotsky (1998). Jacobson and Wilensky wrote: "A central tenet of the constructivist or constructionist learning approach is that a learner is actively constructing new understandings, rather than passively receiving and absorbing 'facts'" (p.22). They believe that this method of learning can increase students' understanding of complex systems as well as be more interesting, engaging, and motivating for students when assigned authentic problems studied within cooperative learning environments. Blikstein and Wilensky (2004) have conducted research in this area of systems thinking with results suggesting pedagogical approaches that involve students generating questions, hypotheses, and theories about a particular phenomenon. Students then develop experiments or create conceptual models using multi-agent or qualitative modeling software to confirm or refute their theories. Jacobson and Wilensky (2006) recommended a constructivist approach to teaching systems thinking within a team or group-learning environment.

Wankat (2002) and Becker (2002) agree that a constructivist approach is critical to improving the teaching of engineering and technology education. Reflecting on the work in *How People Learn* (Bransford, Brown, & Cocking, 2000), Wankat believes that the student, not the teacher, must be in the "driver seat" of learning. Bransford et al. described four critical perspectives of learning environments:

1. *Learner centered* – "Teachers must pay close attention to the knowledge, skills, and attitudes that learners bring into the classroom" (p. 23).
2. *Knowledge centered* – "Attention must be given to what is taught (information, subject matter), why it is taught (understanding), and what competence or mastery looks like" (p. 24).
3. *Assessment centered* – "Formative assessments – ongoing assessments designed to make students' thinking visible to both teachers and students are essential" (p. 24).
4. *Community centered* – "A community-centered approach requires the development of norms for the classroom and school, as well as connections to the outside world, that support core learning values" (p. 25).

Becker (2002) explained that a constructivist approach is inherent in the *Standards for Technological Literacy*, and that a shift from behaviorism to constructivism is critical to educate and assess today's students so that they are prepared for today's global economy. Wankat warned against the *content tyrant,* a phenomenon that takes place when the teacher lets the need to cover certain content control the teaching and learning that takes place in the classroom, something that has plagued engineering education for years (National Academy of Engineering, 2004).

Crawford (2001) suggested that there are five key strategies to actively engaging students in a constructivist approach to teaching. These five strategies are:

- *Relating* — learning in the context of one's life experiences or preexisting knowledge
- *Experiencing* —learning by doing, or through exploration, discovery, and invention
- *Applying* —learning by putting the concepts to use
- *Cooperating* – learning in the context of sharing, responding, and communicating with others
- *Transferring* – using knowledge in a new context or novel situation, one that has not been covered in class.

Contextual Learning

Notice that the constructivist teaching strategies suggested by Crawford, Wankat, Becker, and Bransford et al. emphasize the critical importance of *context* for effective teaching and learning. Contextual learning as described by Borko and Putnam (2000) is situated, distributed, and authentic. They suggest that all learning should take place, or be situated, in a specific physical and social context to acquire knowledge that is intimately associated with those settings. Borko and Putnam also advocate that for transfer of learning to occur, students must be provided with multiple similar experiences allowing an abstract mental model to form. Hanson, Burton, and Guam (2006) proposed contextual learning as a key strength for technology and engineering education programs, allowing for transfer of knowledge from core subjects. Additionally, they suggested that contextual learning is a key concept in helping technology education align with *No Child Left Behind* and providing learning opportunities for students to become prepared to work in a global economy. The context of learning is also essential in designing a solution to an ill-structured problem. Glegg (1972) suggested that the context in which a solution will be applied is not only an important design consideration but also critical to learning design. Teaching engineering design must be done within a context that is authentic. Newmann and Wehlage (1993) suggested that authentic activities have the following dimensions:

- Involve higher order thinking where students manipulate information and ideas
- Require a depth of knowledge so students apply what they know and are connected to the world in such a way that they take on personal meaning
- Require substantial communication among students
- Support achievement of all through communication and high expectations of everyone contributing to the success of the group.

Hutchinson (2002) suggested that problem-based learning is an additional field of inquiry worthy of consideration. Problem-based learning presents students with a problem situation and then they are asked to determine what is happening. "Problem solving, in this approach, involves a process of a) engagement; b) inquiry and investigation; c) performance; and d) debriefing" (Hutchinson, 2002, p. 4). Pierce and Jones (2000) suggested that the worlds of contextual learning theory and problem-based instruction can converge to produce highly conceptualized learning focused on questions and problems relating to real-world issues. Problem-based instruction is self-directed and collaborative. Authenticity of problem-based instruction is accomplished by encouraging dialogue with practicing experts and the manipulation of real data. Hutchinson also suggested formative assessments and performance of students before a panel of experts. These methods have been used successfully in engineering to develop critical thinking skills in students (Woods, Felder, Rugarcia, & Stice, 2000).

Engineering Design and Systems Thinking: The Ideal Context for Problem and Project Based Instruction

Wicklein (2006) and Daugherty (2005) endorsed engineering design as an ideal platform for addressing the standards for technological literacy (ITEA 2000/2002), while also creating an instructional model that attracts and motivates students from all academic levels. Today's workforce requires job skills that move beyond excelling in the basic core subjects (Grasso & Martinelli, 2007). A national employer survey identified desired job skills needed in today's workforce. Today's jobs "…require a portfolio of skills in addition to academic and technical skills. These include communication skills, analytical skills, problem-solving and creative thinking, interpersonal skills, the ability to negotiate and influence, and self-management (The National Center on the Educational Quality of the Workforce, 1995, p. 3). Dearing and Daugherty (2004) conducted a study to identify the core engineering-related concepts that also support a standards-based technology education curriculum by surveying 123 professionals in technology education, technology teacher education, and engineering education. The top five ranked concepts were:

1. Interpersonal skills: teamwork, group skills, attitude, and work ethic
2. Ability to communicate ideas: verbally, physically, and visually
3. Ability to work within constraints/ parameters
4. Experience in brainstorming and generating ideas
5. Product design assessment: Does a design perform its intended function? (p. 9).

The researchers surmised that these concepts, based upon the standards for technological literacy, were ranked high due to the nature of the work environment in today's society and the need for a growing diverse workforce. Hill (2006) recanted Richard Miller's words at a University of Georgia engineering conference about the need for engineers who have excellent communication skills, ability to work in teams, skills in social interactions, and good business ethics. Hill suggested that technology education is an ideal program to team up with engineering education to help young people develop these attributes. Roman (2004) considered the needs of an American workforce struggling to survive in a global economy. He wrote: "Thinking globally requires individuals who can think multi-dimensionally, integrating the technical and economic aspects of problem solving with the social, political, environmental, and safety concerns" (p. 22).

The Engineer of 2020 indicated that the engineer of the future will need to work in teams to study social issues central to engineering (National Academy of Engineering, 2004). McAlister (2003) observed that four of the twenty Technological Literacy Standards address technology and society, so teaching the social/cultural impacts of design is appropriate. We suggest using a systems thinking approach to engineering design to study technology-related social problems because this platform is an excellent way to foster technological literacy and promote the attitudes, thinking skills, and job skills listed above. However, this approach should not be applied to social engineering (Weinberg, 2003).

What is Systems Thinking and Why is it Important for Technology Education?

What is systems thinking? Jacobson and Wilensky (2006) wrote:

> Complex systems approaches, in conjunction with rapid advances in computational technologies, enable researchers to study aspects of the real world for which events and actions have multiple causes and consequences, and where order and structure coexist at many different scales of time, space, and organization (Jacobson & Wilensky, p. 12.).

Kay and Foster added: "In short, systems thinking is about synthesizing together all the relevant information we have about an object so that we have a sense of it as a whole" (Kay & Foster, 1999, p. 2). Mapping out the complex issues of a system by reducing the system down to its parts and studying the relationships within those various parts is a process that leads to a better understanding of the system. Furthermore, tensions may be identified that will likely emerge when a new approach to the system is taken. Failing to understand that these tensions exist and that the system contains these complex relationships, will likely result in a poor, inappropriate design. It is critical to understand that these relationships impact the entire system and the manipulation of one relationship, in turn, affects the entire system. Biologist Lewis Thomas wrote:

> When you are confronted by any complex social system, such as an urban center or a hamster, with things about it that you're dissatisfied with and anxious to fix, you cannot just step in and set about fixing with the hope of helping. This realization is one of the sore discouragements of our century…You cannot meddle with one part of a complex system from the outside without almost certain risk of setting off disastrous events that you hadn't counted on in other, remote parts. If you want to fix something you are first obliged to understand…the whole system (Thomas, 1974, p. 90).

Bar-Yam (2002) confirmed this dogma by making the case that the ability of science and technology to expand human performance through design is dependant upon the understanding of systems and not just the components that lie within that system.

> The insights of complex systems research and its methodologies may become pervasive in guiding what we build, how we build it, and how we use and live with it. Possibly the most visible outcome of these developments will be an improved ability of human beings aided by technology to address complex global social and environmental problems, third world development, poverty in developing countries, war and natural disasters (Bar-Yam, 2002, pp.381-382).

Frank (2005) makes a strong case for a systems approach for technology education. He pointed out that, traditionally, engineering and technology education used a bottom-up instructional approach, one that attempts to determine and deliver all the knowledge and skills needed by compartmentalizing the subjects: a separate math course, a physics course, statistics, etc. Frank proposed a different approach.

> Based on the systems thinking approach, what follows is a proposal for a way to teach technology and instill technological literacy without first teaching the details (for instance, electricity basics and linear circuits for electronics, or calculus and dynamics basics for mechanical engineering) (p. 20).

The premise to this approach is that complete systems can be studied conceptually and functionally without needing to know the details, a top-down approach. A top-down approach focuses on characteristics and functionality of the entire system and the interrelating subsystems. This approach to teaching engineering design addresses issues raised by some that suggest teaching engineering design in technology education excludes some students who have not had, or lack, an aptitude for upper level math or science. A top-down approach also provides a feasible solution to high school courses with students enrolled at various stages of learning, for example, freshmen and seniors in the same class. These issues are of great concern when suggesting that technology education with an engineering design focus is for all learners.

Frank also shares the benefits of project-based learning for technology education that include student engagement, increased motivation, and increased multidisciplinary knowledge, to name a few. Shepherd (1998) found through research that students who experienced project-based learning in a real world setting had significantly higher scores on the Cornell Critical Thinking Test compared to students in traditional instruction. Project-based learning requires students to work in teams to build a product. A misnomer in technology education is that the product created must be tangible, but Frank brings clarity to this issue. He writes:

> The product may be something tangible (such as a model/prototype, a system or a robot), a computerized product (such as software, a presentation, or a multimedia product), or a written product (such as a report, an evaluation summary or a summary of experimental findings (p.21).

A common concern in moving technology education toward engineering design is what will happen to the traditional hands-on projects that produce a physical product? We believe that the best answer to that question is to identify and understand appropriate engineering related problems to be explored in technology education. Some problems will lend themselves to tangible products while others will not. Technology educators will need to accept the idea that not every problem solving activity will or should require a physical prototype or artifact.

Why Systems Thinking and Engineering Design for Technology Education?

If technology education is to be successful in implementing a new program with an engineering design focus, it must be able to articulate the idea that learning engineering design can generate a type of thinking that can be applied to many occupations. With the application of engineering design and systems thinking, students learn how to use critical thinking skills to solve complex, ill-structured problems that are necessary to live and function in the 21st century, regardless of whether the student plans to work in a factory, on a farm, or in a courtroom. No matter what occupation students select, they will encounter many ill-structured problems, none of which can be solved with a single textbook answer. Engineering design and systems thinking provides a systematic approach to solving ill-structured problems which is a vital, universal skill that can transcend all vocations.

Conclusion

In an educational field such as technology education that has been accused of poorly communicating a clear mission (Wicklein, 2006); it appears appropriate to consider a new theoretical foundation for the field. Moreover, as new demands arise for educational programs that will equip the next generation of workers who are trained to survive and thrive in a global economy, a new philosophical framework for technology education may be needed. In this article, the authors have attempted to provide a philosophical framework for technology education that holds true to some pedagogical approaches that are at the heart of the success of technology education (contextual learning, problem-based instruction, and project-based instruction), while at the same time embracing new philosophies of learning and thinking (constructivism, engineering design, and systems thinking). The current literature is clear about the type of workers needed for today's global economy (Pink, 2005; Friedman, 2005; National Academy of Engineering, 2004; National Academy of Engineering, 2005; Woods et al., 2000). If technology educators determine that their purpose is to help prepare students to live and work in this global society, then these educators should consider carefully defining a philosophical framework upon which to build a new curriculum. The authors wish for technology educators to consider the proposed framework as a foundation for technology education as it has much promise in preparing students to function in today's technological society.

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