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From the Editor

You Can't Get Here From There

Like most everyone these days, there is an ever-widening location in my mind in which I place thoughts and emotions about the economy. At this point I can say with confidence that no one has been untouched by its tumble. Though I think about the effect that it has had on me personally, I also wonder what effect it will have on education. Schools in my area are already engaged in the usual behaviors that accompany budget problems – money remaining in budgets for programs like technology education is moved to other purposes, searches for new personnel are terminated, field trips are cancelled, and employees are asked to look at every possible way to conserve increasingly valuable resources. Plans for the next wave of budget cuts will likely include layoffs of support personnel and reduction in the work week for others.

"The older the wiser" is an adage that has a rather universal meaning in most parts of the world. At my age, I guess one could say that about me, but the truth is, whatever wisdom I might have had seems to be increasingly replaced by caution tempered with a bit of plain fear. Just like the cold chill that still runs up and down my spine when I start to slide while driving on ice, harking back to bad experiences I had as a teenage driver on wintry roads in Montana, the current economic situation produces the same chill as a result of some prior experiences. One great advantage of being a teacher is having the opportunity to work with young people. Their optimism, though arguably based on naiveté, is foundational to a positive outlook for those of us who might be teetering. It also brings credence to the strength of decision making when decision makers represent the full range of age diversity.

Those critical experiences, the ones that we remember for years after they occur, significantly shape our beliefs and resultant behavior. My father was just getting his dental practice started about the time the Great Depression began. I remember him relating how he sat in his dental chair, day-after-day, waiting for his first patient to make an appointment. It took over six weeks before that happened. Not long after that, the economic woes hit with a vengeance. For a long time he refused to put money in a bank. The only bank loan he ever had was for the house in which we lived, something he paid off in half the loan term. He saved in order to pay cash for a new car and as soon as he bought it he began saving for next one, methodically eight years down the road.

I never followed my father's economic example. As near as I can tell, none of my three children followed mine either. Across the three generations, each was less conservative than the previous. I am confident, though, that because of his experience my father could weather another depression much better than any of his offspring.

Reflections about these critical life experiences that form our beliefs and forge our uncertainties have led me to a possible explanation for an enigma about which I have been puzzled for years. Permit me to illustrate with an example, embodied in a technology education professor fictitiously named Smith. Though the example is a professor, it could apply to virtually anyone in the profession. As you might suspect, at least some of it applies to yours truly. In any event, I have seen the scenario unfold many times throughout my career.

Smith has been teaching technology education for over twenty five years, now. While in high school he had a wonderful experience in industrial arts. He was especially fond of what he was learning in the use of tools and equipment, the emphasis of the classes he took. He especially liked woodworking. As a result he enrolled in an undergraduate program, preparing him to be an industrial arts teacher. He found in his collegiate studies the same emphasis on the use tools and equipment. Through his four undergraduate years, he honed his skills and knowledge in a variety of areas, but his favorite was still woodworking. He loved being empowered to make close-fitting dovetail joints, applying high quality finishes, operating machines with confidence, and using hand tools deftly. His desire and motivation to develop these same feelings in young people made him increasingly excited about the teaching career in which he would soon embark.

In his third year of teaching, he was presented with an outstanding teaching award. He encouraged his students to enter the projects they had made in his class into competition with students across the state. They began to earn the top awards in the competitions, bringing accolades from other teachers, the administration, parents, and members of the community in general. Many more students wanted to take his classes than there was space available. Smith got involved in state and then national organizations. He earned a master's degree. The same feeling that he had in high school that led him to become a teacher started to motivate him to become a teacher educator. He knew that he was a good teacher and had some unique talents. Increasingly he felt that he could make a unique contribution to preparing others to become good teachers. He applied for doctoral study.

While in his doctoral program, Smith increasingly reflected upon his career and how his values and philosophy had changed over time. He decided years ago that there is much more to technology education than simply developing tool skills and avocational interests. He did a lot of reading and followed very closely the changes that were occurring in his profession. The fire that he had in his heart to enter industrial arts in the first place was burning even stronger to become a technology teacher educator. With solid experience as a teacher, he was able to make sound decisions about the direction he felt the field should take and how he would convince his soon-to-be teacher education students of the logic of the new directions in the field. He had the zeal of a religious missionary.

Armed with enthusiasm, experience, and knowledge, he continued his teaching career at a university. He could not wait until he met with his first professional education class. He expected that the students would be as excited to learn about the new curriculum in technology education as were the students in his woodworking class years earlier. He was disappointed. Though many of his students nodded their heads in affirmation of the ideas he was presenting, others were not accepting of them at all, challenging Smith in ways that sometimes bordered on disrespect. The air of his balloon of enthusiasm was nearly all gone, making him feel defeated, and at times even angry.

Smith thought that it would be a simple task to move his students forward to his philosophy. Despite the huge variability in the viewpoints of the students coming into the class, he felt that he could change their basic beliefs by giving them a didactic treatise, based in logic and substantiated by leaders in the profession. In doing so, he ignored constructivist theories of learning. He did not consider that what he believed quite likely occurred *because of* his early experiences – that these early experiences were foundational and essential to his philosophy. In other words, he could not get here with being there first.

I could not fully understand my father's economic philosophy because it was based on his direct experience with the Great Depression. He expected that he could transmit his economic beliefs to me by providing logical arguments relative to borrowing, spending, and saving. What he did not take into account is that the foundation of his philosophy was based on what he personally experienced in the Great Depression and there is no way I could relive those experiences directly to make me a "true believer."

So, the challenge then is to figure out how to get our aspiring teachers here from there, recognizing that we cannot provide them with the same direct experiences we had in the journey. We must recognize that "there" is different for each person. Not doing so is analogous to giving the same set of directions to a specific location to everyone, regardless of where they are in the world.

JEL

Articles

The Roots of Technical Learning and Thinking: Situating TLT in Schools

Ron Hansen

Technical thinking is defined as an aptitude, ingenuity, and affliction for solving practical problems through experience (Autio, Hansen, 2002). From the beginning of civilization such thinking has been a significant part of human existence (Burke & Ornstein, 1995; White, 1962). Learning associated with it is a natural instinct for most people, young and old, who work in a technical field, pursue a practical hobby, or teach practical subjects. Historically the learning process, when formalized, involves apprenticing with a master who passes along the knowledge and competence by showing, doing, and discussing. Today such formal apprenticing is considered by many to be misplaced and inefficient. Why can't the knowledge and competencies associated with technical thinking be taught using computers and books?

A closer examination of the basic nature and form of technical thinking and the pedagogy that drives human thought about it helps address the question and underscores why the question, rather than apprenticeship or experiential learning itself, is misplaced. It is generally accepted in the education literature, classic and more recent, (Gamble, 2001; Lehmann, 2007; Willis 1974), that technical programs in schools are rooted in economic rather than social soil. Adolescents and young adults are "trained" with workplace skill, enculturation, and human capital in mind. Willis initially, and Lehmann more recently, refer to this pedagogy as "learning or choosing to labour."

The social soil is more difficult to understand. Cygnaeus, (cited in Kananoja, 1999) when he founded the Finnish school system in the 19th century, was the earliest to articulate the social view. He pinpointed a human learning characteristic that he felt was central to the health and development of children and adults. Referring to the benefits of handwork for children Cygnaeus argued the pedagogical aim of technical learning was to develop the eye, the sense of

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form, and general dexterity. Harre and Gillett (1994), one hundred years later, refer to this human tendency as having a "sense of physical location." They argue that perceptual and motor skill in the physical and material world give human beings a sense of self and intelligence.

Technology teachers in England, Germany, and Canada, a recent study (Hansen, 2002) concluded, were intimidated by the dominant academic milieu they found in schools. "Technology teachers, it was found, spend their careers unconsciously resisting a way of learning and behaving in their schools that, to them, is dysfunctional. As such their socialization into the profession is problematic." (p.10).The relative value of an experiential versus didactic pedagogy was a persistent issue. German technology teachers, by comparison, did not have to cope with status and stratification issues in their schools. There were none. Probing the roots of technical learning and thinking makes it possible to "reconsider" technical education in our schools.

Research Method and Analysis

In life-story research (Cole, 1991), the conversation between the investigator and the interviewee is usually dominated by the participant who is asked to freely recall and reflect on life experiences. The researcher, Cole asserted, maintains a passive role, merely probing these recollections and reflections. The purity of such accounts can range from strictly autobiographical to what Connelly and Clandinin (1990) call "collaborative stories." "And in our story telling, the stories of our participants merged with our own to create new stories, ones that we have labeled 'collaborative stories'" (p. 12).

This research takes as its focus the process of autobiographical career reflection of one subject, "Sandy," for making sense of the shifts we all have to undertake in education. It makes use of the personal writing of one person who was selected because, although his career in many ways was atypical, he articulated some of the difficulties in adjustment which many technology teachers would not acknowledge because normally they don't question the school milieu into which they assimilate. He has documented a "critical incident" (Tripp, 1993) which influenced his career path and his disposition, both toward technology teaching and towards the nature of technical learning itself. The manuscript, using his critical reflection, sets the stage for other technology teachers to engage in similar reflection about their own development and enculturation.

A critical theorist perspective on schooling (Greenfield, 1993, McLaren, 1998) is used to provide context and understanding for this autobiographical research. The purpose of the research is to create insight and perspective for the reader, as well as to critically examine the assumptions upon which school curricula are based. What is the nature of technology and of teaching in schools? As nations and economies rush to claim a "knowledge-based" lifelong learning model, the need for technical education to have its true nature and form properly recognized and valued, in and out of formal learning institutions, is crucial.

Sanderson "Sandy" – Reconstructing Experiential Learning Tendencies

Consensus on how people learn often eludes us as formally trained educators. We overlook or don't acknowledge what we know about how people learn from our own experiences. The following excerpt from Sandy's (a pseudonym) technological education journal conveys, with conviction, how learning occurs when it happens outside of the formal school environment. Readers will know of others from their own lives and experiences.

> *The most important insight which I learned about myself as a learner [in school] was that it did not matter to me what other people thought about my potential, I knew it was unlimited. Unfortunately I also came to oppose authority constantly. Many years passed before I began to respect people in authority. I was not aware of it at the time, but I demonstrated my true nature of learning, and emphasized in myself a return to the initial method of learning that all of us employ. I reconstructed my experiential learning tendencies. Unfortunately, the experience was not a good or constructive one and I became someone who would not trust or respect teachers until they could prove themselves to be a person who treated all others with respect and trust. Still to this day if anyone suggests that I am not capable of a task, I catch myself working hard to prove them wrong. In some ways this is good, but I have to pay close attention to my actions so as not to overreact.*
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> *From my perspective at the time (and I strongly believe this today) it became apparent to me that the most effective learning environment is one where the educator is able to set aside personal prejudice and focus on the needs of each individual. By doing so you can more effectively provide the area of individual attention that each student requires. This applies to all aspects of any work environment in which I have been employed. I certainly did not fully understand my learning tendencies then, but I am beginning to now. I am, by nature, a hands-on experiential learner and my schooling did not allow me to develop my learning style to any significant level from which my full potential could be realized. During my time in school my parents and teachers all emphasized how important it was to learn and do well in school. I did try to adapt my learning tendencies to suit their perceived views on how to study and learn, but I was only able to achieve limited success through these methods. This made school a difficult place for me to be because I did want to please my parents, but I was unable to explain or understand why I could not achieve the grade levels that we all knew I could. I was trying hard to adapt my learning style to what my parents and teachers thought it should be, and I did achieve limited success.*

What this journal vignette reveals is that the values and beliefs that differentiate academic studies from practical learning are discernible, but repressed. Sandy's reflections help the reader understand the dynamics of two distinct learning cultures, and their impact on situating technical learning in the school curriculum.

Sandy is particularly strong and articulate in expressing his less than stellar experience as a learner in schools. He had a number of demeaning experiences that, to this day, remain vivid in his memory. One could argue that he is ignoring the fact that many students experience problems or undergo some trauma in school life. In hindsight, many parents and students appreciate the discipline that school life imparts. On the other hand, some who think they are better off for schooling experiences may not have confronted their feelings fully or thought through what really happened. Sociologists are often quite blunt about the latent dysfunctions of the school. Bowles and Gintis (1976) argued, for example, that schools do not reduce or remove class inequities, they perpetuate them. At the individual student level, British sociologist Basil Bernstein (1970) argued that learning in schools serves middle class children (with strong linguistic orientations) well and deprives working class children (with strong non-discursive tendencies). "Thus the working class child may be placed at a considerable disadvantage in relation to the total culture of the school. It is not made for him [sic]: He [sic] may not answer to it." (p. 346). This point is further reinforced by the writings of Margaret Donaldson (1987): "The better you are at tackling problems without having to be sustained by human sense the more likely you are to succeed in our educational system, the more you will be approved of and loaded with prizes." (p. 78).

What this journal excerpt reveals, beyond personal growth, is that preparing to teach technology is complicated. What technology teachers are preparing for and practicing to do in their chosen profession is perplexing to them. They have, like many teachers, a set of baggage relating to their own schooling that may or may not be resolved in their own minds. What are my tendencies as a learner? What are my beliefs about learning, studying, and experiencing? These teachers experience a dissonance between value systems. Their success and self-esteem were measured, not by book studies and normative grading, but by experience and everyday technical, economic, political, and social reality. The view expressed by this technical teacher candidate eschews the way learning in schools is defined and perpetuated, and school life generally.

Beyond Knowledge to Experience – Examining the Assumptions Underlying Schooling

The technology and general studies curriculum in secondary schools in the developed countries around the world is one that has evolved and is evolving in response to a range of pressures and perceived needs. The widespread belief is that industrial countries are in a significant economic transition and that formal education is the key to economic and social survival. "Skills for the New Economy" is the catch phrase across many fields/sectors (usually meant to be computer or information handling skills). Alternatives for organizing or improving the curriculum are discussed and debated but with little meaningful change to the general landscape. Some reviews of the classic curriculum literature (Bernstein, 1970; Donaldson, 1978; Eisner, 1998; Rogers, 1999; Sheridan, 2000) look at alternative ideas for organizing the curriculum in schools but those ideas never materialize. Why is this? Why are academic studies such a given in western societies? Why do subjects like technological education live in the shadow of academic studies? While the purpose here is not to answer these questions, Sandy's reflections give rise to them. The critical position taken by the author is that the knowledge transmission process in schools and the formal institutionalization of learning both displace rather than situate subjects like technology in the curriculum. A wholesale analysis of the heart and soul of the academic curriculum, and the educational sciences approach that created it, is overdue. Providing a critical examination of school knowledge, institutionalized learning, and the awkward position of technological education teachers like Sandy, are possible, but only when the assumptions upon which school curriculum is based open themselves to scrutiny.

Schooling assumes assimilation into society via academic achievement is an exclusive right and necessity for all citizens. This assumption is predicated on the notion that matters of the mind are superior to matters of the body and spirit. Evidence from recent research reports (Harre and Gillett, 1994, Kessels and Korthagen, 1996), however, suggests that the same "academic-diet-for-everyone" assumption is flawed. Assumptions like these lead to a devaluing of subjects like technology in the school, not to mention art, physical education, drama, and music. There are three assumptions that Sandy's testimony provokes us to consider in order to better understand the magnitude of the problem: a) book learning in schools is an irreproachable method by which to learn, b) an academic curriculum enhances human development and self-esteem, and c) a knowledge-based curriculum is superior to an experience-based one (Hansen, 1996, 2002). These will in elaborated in what follows.

Book learning in schools is an irreproachable method by which to learn.

Layton (1993) suggests technological education "challenges the historic role of schools as institutions which de-contextualize knowledge" (p. 15). Its [technological education] very essence is the antithesis of the general studies curriculum (including what is taught and how it is taught) in the comprehensive secondary school. More recent scholars (Noddings, 1995; Sheridan, 2000) suggested that new ways of thinking about learning, new ways of understanding the relation between learning and personal development, and new ways of structuring formal learning over the life-span, are worthy objectives. While these sentiments are welcomed, the evidence they marshal and the arguments they frame do not go far enough. When analyzed, their efforts confirm or reveal something that was identified by Borish (1991) in his study of schools in Denmark. That is, principles and practices that were originally conceived to be the founding philosophy of schools have been abandoned or eroded. Their [schools] purposes somehow became skewed and lost their realness. In his essay on how schooling contributes to a legitimacy of literacy at the expense of experience Sheridan exposes the problem:

> For hundreds of years, knowledge and ways of knowing in most of settler culture (and longer, for some sectors of it) have included alphabetized, literate media. For thousands of years there has been an oral tradition in indigenous cultures. That is history. There is also the history of attitude here. Literacy and orality are valued and legitimized differently, and the difference in how we have valued those is part of our joint history. Schools teach literacy. There is no question that literacy is a good thing. The issue is the consequence of assuming that literate definition has priority (p. 23)

McLaren's (1998) argument that school systems in western society are not egalitarian, nor do they augment economic, cultural, and political structures is further evidence of the problem. A great opportunity to better understand what is missing in the life of school systems becomes possible when nothing is taken for granted and the needs of students and communities are put ahead of the needs of the government, industry, and school systems. One of the best historical examples of this phenomenon was documented in the Finnish school system.

Schooling, the Finnish scholar Lindfors (1999) concluded in her historical analysis of sloyd (learning of crafts), represents an artificial environment in which to achieve the grand goals that we all have for our youth, e.g., cognitive, emotional, and psychomotor growth. "When schools took over responsibility for teaching sloyd, the goals as well as the content became artificial. Sloyd was to offer material as well as formal education. Both the usefulness of learning sloyd skills (instrumental and economic aspects) and the fostering aspects were included in the educational goals of sloyd. In practice there was a contradiction between these two directions." (p. 14). Missing from our analysis of schooling, the author contended, is an honest assessment of the advantages and disadvantages that 12 years of institutional confinement and academic programming brings. Sociologists are one of the few groups who understand that schools perform positive and negative functions for society. The positive functions can be found in the school literature in the form of goals and purposes. The negative functions are not well understood or discussed widely. They include the "holding" function that schools perform on behalf of society, the conformity function, and the standardization function. The "Our schools/Ourselves" monograph series (1992) pointed out that schools construe learning in one way only. As graduates of our schools, most of us have come to accept that the way in which knowledge is packaged and dispensed in schools is a given. This "knowledge packaging and absorption process" may be problematic.

An academic curriculum enhances human development and self-esteem

The assumption that book learning and an academic curriculum are essential to human development, fulfillment and self esteem is the most prominent and unchallenged assumption underlying schooling. The assumption implies that such learning enhances both personal and cognitive development. The universal belief is that there is a correlation between cognitive and personal development, and that academic endeavor is essential and exclusive to it.

Harre and Gillett (1994) have contributed significantly to the explanation of what enhances personal development in human beings. They refer to the importance of having a "sense of physical location." They conclude that having a sense of physical location is what leads to self-esteem, not academic accomplishment. Self-esteem is an essential ingredient that is often missing in young learners who find that life in school drains, rather than builds, their self-confidence.

In technological education, learning involves utilizing a range of sense-making capacities and assumes physical action, as well as knowledge acquisition, as essential components for understanding. Technology students have the chance to develop a practical wisdom much like that developed by technologists, engineers, and technicians in the workplace. Unfortunately their success in achieving this wisdom is tempered by the models of learning that are perpetuated in teacher education institutions and in general studies subject matter. The true pedagogy associated with practicing technology goes unheralded. This phenomenon is identified by Lindfors when she laments how the goals and content of sloyd became artificial when transferred to schools. The problem exists to this day in most western societies, not because of technology teachers who fail to recognize and do something about it, but because the curriculum framework and teaching methodology they are expected to adopt is philosophically too narrow to include their workplace and life experience preferences for learning.[1]

What Lindfors' work conveys is that existing conceptions of schooling/knowledge do not take into account other important variables that ultimately shape our development as human beings such as economic and workplace realities, cultural differences, and family diversities. In other words, schooling, by virtue of singling out specific aspects of knowledge for dissemination to our young is too narrow or oblique in its purpose to help children grow in the fullest sense. To be more complete, schools would have to cast human learning in a broader light to include, for example, learning about other ways of knowing.

Schools, Lindfors would say, cannot help but be artificial places because they are removed from everyday community reality and they do not attempt to

[1] This situation is especially acute in Canada, where technology teachers often are required to have work experience in their technical field before they can qualify for teaching. Their tendencies and preferences for learning are very much associated with the nature of problem solving in their respective workplace and technical field rather than with a school system prescribed formula for learning.

relate school to life! School goals and content are constructed or manufactured. They are places where we simulate learning.

Knowledge-based curriculum is superior to an experience-based one.

Knowledge is the keystone or central element upon which institutionalized learning is based. This highly regarded commodity has been elevated to such a high degree over recent years that it is taken as a universal and exclusive standard for achievement and success. The irony is that most knowledge conveyed in formal education institutions is constructed knowledge. It is packaged, one might say, for delivery and consumption the same way a new product is for the retail market. It is referred to now as "school knowledge" (Eisner, 1992). There is a further problem. Its consumption does not lead to individual development, at least not for everyone. Knowledge in schools and in Western society is generally portrayed and legitimized at the expense of "experience" – life and work experience (Sheridan, 2000). Literature about the sociology of knowledge explains this irony quite effectively (McLaren, 1998). Conceptions of "experience," by comparison, do not exist and are not felt to be important. Experience is devalued compared to knowledge.

The assumption that knowledge-based learning leads to understanding is the single most prominent but unchallenged assumption we make as educators working in formal education institutions. This subtle but widespread hierarchy of growth, that information leads to knowledge and then to understanding, is flawed. The first part of the continuum is defensible. We do transfer much information to children in our school curriculum (especially so in this information society) and the sorting of that information does lead to a distillation, and to knowledge. The second part of the continuum is not defensible. It is impossible to achieve understanding from knowledge alone – experience intervenes (Boud, 1989). Education philosophers like Dewey have documented the flaw in this assumption.

In the school context we exclude the world of experience as if it were somehow alien to students. Imagine a curriculum organized around problems as opposed to subjects, to human development rather than human differentiation. Experiential learning advocates (Kolb, 1984) have shown how human learning, when it is self-directed, is very much based in personal experience. But when it comes to youth, we put knowledge ahead of experience. The constructivist learning literature (Driver, 1989) suggests that young children do have an experience base onto which new learning can be attached. The irony is that our highly trained general studies teachers themselves have a narrow base of experience from which to draw. In Canada, this is very much the case. The teachers who enter the profession in our country are the high achievers from university systems. They are not required to have any work experience in their respective fields or disciplines. They have mastered a narrow conception of knowledge. Furthermore, their attraction and ultimate certification ensures that the system, as it is currently construed, perpetuates itself.

Discussion and Implications

This analysis, rebellious as it is, sets the stage for a critical analysis of our reliance on knowledge versus experience in our policy and planning as educators; an honest and critical look at the premises we take for granted in the formal education system is possible. Sandy's journal entry implores us to re-think and clarify our assumptions about learning in schools generally, and the importance and place of technological education in that learning. Experience and knowledge need to be more transparent in our analysis of educational policy and planning. Experience needs to be considered as an "organizer" for curriculum in learning institutions and a more central and valued component in curriculum design. Challenging conventional thought about educational change is difficult. Technological education may be the one subject that challenges the academic tradition – a tradition that continues to de-contextualize knowledge as Layton stated. In short, technological education's most important role may be that of a barometer for reform in schools.

Experience and one's trust in it serves as a positive psychological factor or force in technical learning. The sense of self that Sandy exudes is central to meaningful learning and human growth. Remove it or diminish it, as we tend to do in schools for half the children, stifles both learning and human development rather than nurturing them. Educational psychologists believe knowledge can be acquired independent of practical action. Technology teachers, by comparison, know that such assertions need to be qualified. It might be safe to say that learning in controlled environments such as schools, (learning of a predominantly academic nature), can be separated from learning of a practical nature. That does not mean that such learning is suitable or best for students. Meaningful learning, when students are self-motivated or self-directed in their everyday lives, is extensively based in experience, as Boud attested. To further understand how technical learning has been displaced rather than situated in schools, critical analysis of formal institutionalized learning is necessary. Reform of the knowledge-acquisition model of learning in schools may be more important that heretofore thought.

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Quality and Characteristics of Recent Research in Technology Education

Scott D. Johnson and Jenny Daugherty

The focus of research in technology education has evolved throughout its history as the field changed from industrial arts to technology education (Spencer & Rogers, 2006). With the move to technology education, the field has begun to broaden its focus to better understand the teaching, learning, curriculum, and policy implications of preparing the next generation of technological thinkers. Although a complete "paradigm shift" may not have occurred completely within all technology-oriented programs (Sanders, 2001), the current emphasis on engineering within technology education indicates a need to examine and assess the status of technology education research over the past ten years to identify strengths and areas that need to be addressed in order to guide the field into the future.

Issues of Quality in Educational Research

Scientific inquiry is a continual process of rigorous investigation to answer the critical questions of a discipline. Advances in scientific knowledge are achieved through long term scholarly efforts of the scientific community to create new understanding in the form of models or theories that can be empirically tested (Shavelson & Towne, 2002). Accumulation of scientific knowledge over time is non-linear and indirect and often involves highly contested or controversial results that undergo professional scrutiny, skepticism, and criticism. Through this process research results are questioned, studies are replicated, and results confirmed or rejected. In only the rare case does a single study produce an indisputable result; hence, multiple studies using multiple methods in varying contexts are needed to establish a verifiable base of understanding.

In contrast to the sciences, research in education often does not follow these practices. The Coalition for Evidence-Based Policy, a non-profit, non-

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partisan organization, notes that public policies in the field of medicine have been based on empirical evidence that has resulted in extraordinary advances over the years (Coalition for Evidence-Based Policy, 2002). In contrast, in many areas of social policy, such as education, “billions of dollars are often allocated to activities without regard to rigorous evidence, with poor results” (Coalition for Evidence-Based Policy, 2002, p. 4). As noted in reports from the Council, “randomized controlled trials are widely considered the “gold standard” for measuring the effect of a particular intervention“ (p. 8), however, they are rarely used in educational research and evaluation. An examination of 144 Federal contracts for evaluation studies between 1995 and 1997 found that only five studies used a randomized controlled design to measure impact (Boruch, DeMoya, & Snyder, 2002).

Building on this concern, the National Research Council (NRC) released a report, entitled *Advancing Scientific Research in Education* (Towne, Wise, & Winters, 2005). The authors of the report noted that two pieces of federal legislation, the No Child Left Behind Act of 2001 and the Education Sciences Reform Act of 2002, have brought widespread attention to the quality of educational research. Both acts reflect “deep skepticism about the quality and rigor of educational research” (p. 1) and articulate the need for educational research to be based on strong evidence.

Also in 2002, the NRC released a report entitled *Investigating the Influence of Standards: A Framework for Research in Mathematics, Science, and Technology Education*. The committee examined the influence of standards in K-12 mathematics, science, and technology education and developed a framework to guide research so that “inferences can be made about what is happening in the ‘black box’ between the development of national standards and any impact on student learning” (p. 12).

The U.S. Department of Education also released reports defining rigor in educational research. For example, a report from the U.S. Department of Education’s National Center for Education Evaluation (2003) outlined the following questions that educational practitioners can ask to determine if research is supported by rigorous evidence. First, does the research have quality, as defined by the “gold standard” of research, which involves using randomized controlled trials? Second, is there sufficient quantity of evidence, as defined by the number of trials showing the intervention’s effectiveness? Third, if the intervention is not supported by “strong” evidence, is there “possible” evidence provided through randomized controlled trials whose quality and quantity are good but fall short of offering strong evidence or by closely matched comparison-group studies? If the answers to these questions are “no,” then the research is not supported by rigorous evidence.

In response to the concerns expressed above, the Coalition for Evidence-Based Policy collaborated with the U.S. Department of Education to adopt the central principle underlying the No Child Left Behind (NCLB) legislation that educational activities should be backed by “scientifically-based research.” In 2005 the Secretary of Education announced that the Department of Education would focus its financial efforts to expand the number of programs and projects that use rigorous scientifically based research methods. "The definition of scientifically based research in section 9201(37) of NCLB includes other research designs in addition to the random assignment and quasi-experimental designs that are the subject of this priority. However, the Secretary considers random assignment and quasi-experimental designs to be the most rigorous methods to address the question of project effectiveness" (Scientifically Based Evaluation Methods, 2005, p. 3586).

Recently, the U.S. Department of Education's *Report of the Academic Competitiveness Council* (2007) was released to address concerns within the science, technology, engineering, and mathematics (STEM) disciplines. Focusing largely on research methods, the report highlighted the "critical pathway for the development of successful educational interventions and activities, starting generally with small-scale studies to test new ideas and generate hypotheses, leading to increasingly larger and more rigorous studies to test the effect of a given intervention or activity on a variety of studies and in a variety of settings" (p. 13). The American Competitiveness Council adopted a methodological framework that displayed a hierarchy of methods for evaluating the quality of current and future STEM research. At the top of the hierarchy are experimental methods such as randomized control trials (RCTs), which "enable one to determine with a high degree of confidence if the intervention alone caused observed outcomes" (p. 15). Following experimental methods, the next level of research methods is quasi-experimental approaches that include comparison-groups that are closely matched on key characteristics (e.g., prior educational achievement, demographics, etc.). At the base of their framework were other designs including pre- and post-test studies and designs that may not have careful matching of comparison groups. The hierarchy does not include other methods (e.g., qualitative, survey), however, the Council acknowledges that other research methods are a key part of the research agenda needed to improve STEM education and that these methods can be "rigorous" in their own context.

Many within education have reacted either favorably or critically to these calls for education reform. For example, Borman (2002) agreed with the NRC's call for more rigorous research, stating that in order to "develop and improve programs and practices in U.S. schools and classrooms, research methods must separate fact from advocacy, provide the most believable results, and inform with great confidence the question, 'What works?'" (p. 10). Borman argued that the best answers come from experimental studies because they ensure that the intervention caused the different outcomes in the treatment and control groups. Others within the educational research community, however, have responded critically (Lather, 2004; Moss, 2005; Willinsky, 2005). In particular, Maxwell (2004) argued that the federal reports privilege quantitative methods, "treating qualitative methods as merely descriptive and supplementary to 'causal,' quantitative methods, largely ignoring the unique contributions that qualitative methods can make to causal investigation" (p. 8). In addition, St. Pierre (2006) complained that scientifically based research has "become the 'truth' in education, and that truth is being maintained and perpetuated by a whole network of discursive formations and material practices that are increasingly elaborated by a knowledge/power system that may not be in the best interests of education" (p. 243).

Purpose of the Study

The purpose of this study was to assess the quality and characteristics of the research that has been published within the field of technology education between 1997 and 2007. More specifically, this study was designed to determine the types of research conducted within the technology education field, including the research focus, methods, primary data sources, and data types. The following questions were explored to accomplish this purpose:

1. What types of research have been conducted in technology education over the past 10 years?
2. What research methods have been most commonly used in technology education research over the past 10 years?
3. What types of people and data have been the focus of research in technology education over the past 10 years?

A driving motivation for this study was to explore the extent to which technology education research conforms to Shavelson and Towne's (2002) "guiding principles" of scientific inquiry, and to gauge the alignment of technology education research with the current national trend toward a "gold standard" for educational research methods. Answers to these questions provide insight into the degree to which recent technology education research aligns with the "gold standard" for educational research.

Prior Critiques of Research in Technology Education

There have been a number of prior analyses of the research quality in technology education over several decades. These analyses have been consistent in terms of the concerns that have been raised regarding the overall quality of the research (Foster, 1992; Johnson, 1993; Lewis, 1999; McCrory, 1987; Passmore, 1987; Sanders, 1987). Most recently, Zuga (1997) examined research that was published in the main technology education journals and dissertation abstracts from 1987 through 1993. Zuga found that half of the 220 studies she reviewed were primarily descriptive and focused on curriculum. Zuga outlined four areas missing from technology education research: (a) constructivism, (b) integration, (c) inclusion of all students, and (d) cognition. Constructivist problem-based instruction, according to Zuga, is fundamental to technology education, along with the integration of other subjects, especially science and mathematics. However, she found that few of the published studies explored either of these components. What Zuga found to be most disturbing about technology education research was the lack of research that focused on students. In particular, specific groups of students such as females, ethnic minorities, or those who are physically and mentally challenged have been neglected in much of the research. In addition, few research studies explored cognition within a technology education context. Zuga concluded that the technology education research focus "on descriptions of status and curriculum development points to researchers who are narrow, inwardly focused, and oblivious to the goals of their own field" (p. 213).

Petrina (1998) conducted a similar meta-study of research published from 1989 to 1997 in the *Journal of Technology Education* (JTE). Utilizing meta-ethnography and both quantitative and qualitative analysis, Petrina performed a content and critical discourse analysis of the studies published in JTE. In terms of research, Petrina concluded that of the 96 articles, 62% involved research methods that were either conceptual or descriptive and only 35% of these involved human subjects. In his examination of "analytical units of substance" he found that few studies explored issues such as appropriate technology, class, ecology, gender, labor, race, and sexuality. Petrina concluded that the lack of this type of research indicated a lack of "understanding of the way inequities play out in technology and the trades" (p. 38). Citing a study by Foster (1992) and studies by Zuga (1994, 1995, 1997), he stated that those who examine research in the field have concluded it to be a "malfunctioning practice" (p. 28). Petrina's final analysis of the "state" of technology education research was that "conservative voices are favored and critical voices the exception" (p. 51). For research to be relevant, he recommends that it have "a distinct theoretical component and be cast within particular areas of research practice" (p. 48).

Analysis of Current Research in Technology Education

This study involved another, more recent, examination of the top technology education journals to provide a critique of the current status of the published research. Understanding where we are in terms of research type, method, primary data source, data type, and research focus is a necessary step in improving the quality and impact of research in the future. We asked key leaders in the field to identify what they consider the top research-focused journals in the field of technology education. The following four technology education journals were consistently mentioned by the panel of experts: (a) the *International Journal of Technology and Design Education* (ITDE), (b) the *Journal of Industrial Teacher Education* (JITE), (c) the *Journal of Technology Studies* (JTS), and (d) the *Journal of Technology Education* (JTE). This is essentially the same list of refereed journals that Zuga analyzed in her 1994 study. The only difference is that Zuga included *The Technology Teacher* while this study included the *International Journal of Technology and Design Education*

All of the articles that were published in these four journals within the past 10 years were obtained and reviewed (see Table 1). Articles were selected for further analysis if they explored some issue directly related to technology education and were based on empirical data that was collected through either quantitative or qualitative methods. A guiding rule was that the studies to be reviewed needed to involve the collection and analysis of data. Therefore, synthesis pieces, commentaries, and opinion pieces were not included in the analysis.

The studies that met the above criteria were then reviewed and coded according to type of research, research method, primary data source, data type, and research focus. The initial codes for research type and method were generated from the classification provided in a typical educational research textbook (Gall, Gall, & Borg, 2007). The articles were screened carefully and thoroughly because some of the studies did not explicitly state the method that was used, while for others it was questionable whether the study held true to the method that was stated. For example, many of the studies that were referred to as experimental were actually quasi-experimental because the participants were not randomly selected.

Table 1
Number of empirical articles examined in each journal

Title of Journal	Years Reviewed	Empirical Studies
International Journal of Technology and Design Education	1998-2007	68
Journal of Industrial Teacher Education	1998-2007	48
Journal of Technology Education	1997-2006	54
Journal of Technology Studies	1997-2006	29
Total Number of Articles Reviewed		199

Codes for data source, data type, and focus were developed to provide a general, yet descriptive, term that could be used for generating frequency counts across all articles. The initial codes used to classify the research focus were adapted from the coding scheme used in Wankat (2004) in his analysis of *Journal of Engineering Education* articles. As the analysis proceeded it became clear that modifications to Wankat's coding scheme were needed to better conform to the types of research found in technology education. Changes included combining his Computer and Internet/Web codes into an Educational Technology code, expanding his Gender/Women code to Gender-Race, and adding Opinions-Attitudes and Problem Solving as new codes.

Each article was then reviewed and codes were assigned for the categories of research type, research method, primary data source, data type, and research focus. To determine coding reliability, a second coder reviewed and coded a subset of articles from JTE. This resulted in 38% of the codes being examined by another person. When coding disagreement occurred, the coders discussed and resolved the disparity. For those codes that could not be resolved, a third coder was used to independently assign a final code followed by a discussion to achieve consensus with the original coder.

Results

Types of Research in Technology Education

As shown in Table 2, the majority of the studies were classified as quantitative research, with fewer qualitative studies and a very limited number of studies involving mixed methods. It should be noted however that the low number of mixed methods studies is a conservative figure. Several of the articles mentioned that they utilized mixed methods, although in most cases only one research method was described in the published study and therefore the research was coded accordingly. The predominance of quantitative studies was considerably more than in the Zuga (1997) and Petrina (1998) analyses. Petrina concluded that technology educators had yet to adopt the interpretive methods used by researchers in other "practical" fields, leading to a lack of qualitative studies in technology education research. As revealed in the current analysis, qualitative research has increased within technology education. Perhaps spurred by Hoepfl's (1997) qualitative methods "primer," technology education researchers appear to be rising to the challenge of pursing research questions through a sustained, in-depth analysis.

Table 2
Type of research used in technology education

Type of Research	*n*	%
Quantitative	113	56.8
Qualitative	79	39.7
Mixed Methods	7	3.5
Total	199	100.0

Regarding the primary research method used, the majority of the analyzed studies was primarily descriptive in nature and relied heavily on descriptive surveys (see Table 3). This is similar to Zuga's finding that 65% of the 220 studies she classified were descriptive. Petrina reported that 25% of the studies published in *JTE* were descriptive in nature while Zuga noted that the descriptive research in her review relied primarily on the Delphi technique and mailed surveys. Similarly, Foster (1992) found that the majority of the graduate research in technology education relied on descriptive surveys.

Besides descriptive studies involving the administration of questionnaires, quasi-experimental, correlation, and causal comparative were the next most commonly used quantitative methods. There were no experimental studies that involved true randomization, although this is not atypical for social science research where random selection and assignment of students is often impractical. The use of quasi-experimental, correlation, and causal comparative methods differed dramatically from the analysis reported by Zuga and Petrina, who found that very few studies used these methods. In terms of qualitative methods, interpretive research and case study were the most used, while few studies relied on naturalistic or cognitive methods such as ethnography and protocol analysis.

Table 3
Primary methods used in technology education research

Type of Research Method	*n*	%
Descriptive	80	40.2
Interpretive	32	16.1
Case Study	26	13.1
Quasi-Experimental	23	11.6
Correlation	20	10
Causal Comparative	7	3.5
Delphi	6	3.0
Protocol Analysis	5	2.5
Total	199	100.0

Types of Data in Technology Education Research

Students or teachers were the primary population groups for the reviewed studies (see Table 4). When students were the focus of the study, they ranged from preschool students to adult learners. This is a vast change from Zuga's findings (1997) from a decade earlier and Petrina's more recent findings in 2004. Petrina had concluded that "relatively little time has been spent investigating the practice of technology at the local, school-based level" (p. 35). This, however, no longer seems to be the case. The majority of the technology education studies sampled from secondary education populations (n = 54, 49.5%) followed by college students (n = 36, 33.0%) and primary students (n = 18, 16.5%). Almost one-fourth of the technology education studies involved teachers (n = 40, 20.0%). In the majority of the studies, the teacher population was not defined beyond a general technology education category (n = 22, 55.0%). The number of teachers explicitly specified at the secondary level was low (n = 6, 15.0%), however it is reasonable to conclude that most of the studies classified as "general technology education" would encompass the secondary school category. A few studies focused on pre-service teachers (n = 3, 7.5%) and pre-school/primary school (n = 9, 22.5%) level.

Zuga noted that most technology education studies seemed to rely on a "closed circle of people" (1994, p. 209) that comprise technology educators and industrialists. This narrow scope appears to be widening somewhat within technology education research. The increase in the number of studies focused on students and the inclusion of administrators, parents, and the general public as population groups, while still a small percentage of the total (n = 9, 4.5%), may indicate a discipline that is beginning to extend its research base and perhaps its influence.

Focus of Research in Technology Education

As noted by both Zuga (1997) and Petrina (1998), technology education research tends to rely heavily on perceptions and self-reports rather than observable or verifiable data. As shown in Table 5, this continues to be the case with the majority of the technology education studies relying on subjective data such as perceptions (25.9%) and self-reports (33.0%). Only 16.8% of the studies relied on observable behavior and very few studies relied on objective or verifiable data such as the analysis of test scores (15.7%) review of existing documents (5.6%), verbal protocols (2.0%), and archival data (1.0%).

Table 4
Population groups represented in technology education research

Primary Data Source	***n***	**%**
Students	109	54.9
Teachers	40	20.1
Professionals	19	9.5
College Faculty	15	7.5
Administrators	6	3.0
Documents	5	2.5
Graduates	2	1.0
Parents	3	1.0
General Public	1	0.5
TOTAL	202	100.0

Table 5
Type of data collected in technology education research

Primary Data Type	***n***	**%**
Self Report	65	33.0
Perceptions	51	25.9%
Observable Behaviors	33	16.8
Test Score	31	15.7
Documents	11	5.6
Verbal Protocol	4	2.0
Archival Data	2	1.0
TOTAL	196	100.0

Regarding the primary focus of the research in technology education (Table 6), most studies addressed issues related to teaching (n = 42, 21.1%), curriculum (n = 41, 20.6%), and learning (n = 41, 20.6%). This is consistent with Zuga's finding that 50% of the technology education research she reviewed dealt with curriculum, most often by assessing the beliefs of state supervisors and teacher educators. Foster (1992) also noted that the majority of graduate research in technology education focused on pedagogy, curriculum, and program evaluation. In spite of Cajas' (2000) call for more emphasis on studies of student learning, only 20.6% of the technology education research addressed this critical area.

Table 6
Focus of research studies in technology education

Primary Research Focus	***n***	**%**
Teaching	42	21.1
Learning	41	20.6
Curriculum	41	20.6
Opinions-Attitudes	18	9.1
Design	17	8.6
Problem Solving	9	4.5
Assessment-Evaluation	9	4.5
Gender-Race	8	4.0
Professional Development	7	3.5
Educational Technology	5	2.5
Completion-Retention	2	1.0
TOTAL	199	100.0

Discussion

As indicated in the above analysis, and also in the studies by Zuga (1994, 1995, 1997), Foster (1992), and Petrina (1998), research in technology education has a long way to go before it can be considered "gold standard" research. With no studies in the past 10 years involving randomized controlled trials and relatively few comparison group studies, one would be hard pressed to defend the quality of technology education research, at least when using the U.S. Department of Education's "gold standard" criterion. However, given that this national standard for research is not universally accepted, and given the argument that alternative methods of research can be equally powerful in their own right, it would be difficult to criticize the quality of technology education research along these lines.

However, based on the review of published research provided through this study, it is apparent that the focus, methods, and overall quality and rigor of research in technology education needs to be improved along the same lines as advocated by Zuga, Foster, and Petrina in previous decades. There are indications that Zuga and Petrina's calls for studies focusing on specific issues such as integration, gender, and race have begun to be answered or at least echoed by others. The study by Dyer, Reed, and Berry (2006) is an example of integration within the mathematics and technology disciplines as a viable avenue of exploration. Their study compared the end of year mathematics test scores of high school students who had completed specific technology courses and those who had not. Arguing that "technology education provides a contextual basis for reinforcing the content of the core academic areas" (p. 7), they found that students who took the courses had significantly higher math test scores.

Studies exploring issues of diversity, such as gender and race, are also emerging in the field. For example, Weber and Custer's (2005) study of gender-based preferences set out to describe middle and high school female and male students' preferences for technology education activities, topics, and instructional methods. In addition, Fazarro and Stevens (2004) explored African-American and European-American learning style preferences to understand how these groups of individuals learn, which the authors argue is "essential to designing and implementing the shift in teaching practice so that all students benefit" (p. 5).

It is important to note that research on the teaching of technology in schools appears to be occurring with a large number of studies using students for their target populations. Studies range from exploring elementary students' ideas about concepts and skills associated with structural stability (Gustafson, Rowell, & Rose, 1999) to examining the effects of tests on undergraduate technology education students' learning retention (Haynie, 2003). Unfortunately, many of these studies rely on descriptive methods and perceptions, which leads to a rather superficial analysis of the problems that students face when learning about technology. In order to better understand the teaching and learning process as related to technology education, research needs to provide a deeper examination of the complexities and influencing factors that ultimately impact student learning.

This deeper examination can be pursued in cognition studies, as advocated by Zuga (1997) and others. Petrina, Feng, and Kim (in press), for example, investigated research that examined and conceptualized how different age groups learn technology to better characterize cognition research in technology. They found that much of this research investigates age groups from children to adults in isolation, failing to "conceptualise either how we learn technology across the lifespan or how we might study this problem" (p. 2). The authors offer two broad categories of research methods to help remedy this problem including: (a) design-based research, and (b) cognitive ethnography. Design-based research is an "intervention research with an experimental connotation but its utility is more general in facilitating research in fairly controlled lab and field settings" (p. 15). Cognitive ethnography, on the other hand, "reframes ethnography through distributed cognition, cognitive psychology, and human factors" (p. 14). Cognitive ethnographers use different measures including analogies, concept mapping, audio and video recording, interviewing, observation, think-aloud, and retrospective protocols.

In particular, protocol analysis is a method that few technology education researchers have used to examine the thought processes of individuals while they complete a task or solve a problem (Atman & Bursic, 1998, Johnson & Chung, 1999). Verbal protocol analysis requires subjects to say aloud everything they think to themselves while performing a task or solving a problem. The researcher's task is to take the incomplete record provided by the protocol and infer the underlying psychological processes by which the subject performed the task (Ericsson & Simon, 1984). Such a method can provide insights and clarity of hidden processes that are only conjectures when examined through self-reports of processes and perceptions. The same can be said for the use of video recordings of students while engaged in design and problem solving activities. A careful and thoughtful analysis of their recorded conversations and actions can provide insights into patterns of behavior that would be transparent through other, more superficial, means of analysis (Crismond, 1997).

A few studies that have utilized protocol analysis include Lavonen, Meisalo, and Lattu's 2002 study. The authors examined collaborative problem solving of 8th grade students by video recording activities and then coding the video protocols into episodes. Welch, Barlex, and Lim (2000) also utilized protocol analysis and video recordings in their study of 7th grade student pairs as they produced a solution to a design brief. Likewise, Welch (1998) videotaped pairs of 5th grade students as they completed a design-and-make task. Each of these studies utilized video recordings to carefully and thoughtfully analyze the conversations and interactions of the students to better understand and interpret the particular questions of interest.

There is also a need to better align the focus of research in technology education with the national movement within the field to place more emphasis on engineering, design, creativity, and problem solving. There are examples of studies that have explored these more recent trends in technology education, for example, Dugger's 1994 study of the similarities and differences in the design processes used by engineers and technology educators. Other studies have explored design thinking by comparing expert and novice design behavior (Christianns & Venselaar, 2005; Welch & Lim, 2000).

Creativity is also a line of research that is emerging within technology education as it moves to embrace engineering design as part of its content base. Lewis (2006) has been a particularly strong advocate, not only for research exploring elements of creativity, but also for creativity to serve as an overarching framework for design and problem solving in technology education. A creativity framework provides "opportunities for students to step outside of conventional reasoning processes imposed by the rest of the curriculum" (p. 36). Studies have begun to explore issues of creativity within technology education including computer simulation (Michael, 2001) and assessment (Doppelt, 2007).

Problem solving is another avenue of research that is being explored within technology education. For example, Sutton's 2003 study explored problem-solving research outside the field of technology education; focusing primarily on research from cognitive science and mathematics. Sutton concluded that there are three primary areas of problem solving that are of particular interest to technology education from the problem solver's perspective: (a) the representation of the problem, (b) his or her background and experiences, and (c) his or her understanding of the problem and its structure. According to Sutton, these three areas provide a "fertile field" (p. 59) for problem solving research in technology education.

While there seems to be movement in a positive direction (i.e., a better balance of quantitative and qualitative research; more inclusive studies; and cognition studies) than in the past, the recent collection of technology education research is still dominated by descriptive studies that rely on self-reports and perceptions. As indicated by the national movement toward more scientifically based research in education, the need to raise the quality and rigor of technology education research is apparent. With an increasing focus on STEM education, technology education research can provide the empirical grounding for teaching and learning in these disciplines.

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The Effects of 3-Dimensional CADD Modeling on the Development of the Spatial Ability of Technology Education Students

K. Lynn Basham and Joe W. Kotrlik

Research Framework

Spatial abilities are fundamental to human functioning in the physical world. Spatial reasoning allows people to use concepts of shape, features, and relationships in both concrete and abstract ways, to make and use things in the world, to navigate, and to communicate (Cohen, Hegarty, Keehner & Montello, 2003; Newcombe & Huttenlocher, 2000; Turos & Ervin, 2000). Visualizing intangible boundaries such as state and national borders helps organize, orient, and compartmentalize knowledge of the world. In a similar way, this ability is used to envision new things, and establish relationships of concepts in the mind (Jones & Bills, 1998). One source estimates that 80% of jobs primarily depend on spatial ability, not on verbal ability (Bannatyne, 2003). Surgeons, pilots, architects, engineers, mechanics, builders, farmers, trades people, and computer programmers all rely on spatial intelligence (Bannatyne, 2003).

Newcomer, Raudebauch, McKell and Kelly (1999) reported that people who lack spatial ability are not good at interpreting graphic representations, have difficulty with directions and location of things, or are poor at estimating size or visualizing things and their relationships to one another. Yet, these people successfully function because they have more spatial ability than they realize. Spatial ability can be improved in children and adults (Potter & van der Merwe, 2001; Strong & Smith, 2001). A potential benefit of improving spatial abilities is the improvement of academic achievement in mathematics and science (Keller, Washburn-Moses & Hart, 2002; Mohler, 2001; Olkun, 2003; Robichaux, 2003; Shea, Lubinski & Benbow, 1992).

Educators debate whether increased spatial aptitude improves performance in science and other subjects (LeClair, 2003). Minimal academic training in science focuses on spatial thinking and most assume the existence of necessary

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spatial skills (Schultz, Huebner, Main & Porhownik, 2003). It is suspected that spatial ability contributes additional validity to mathematical and verbal reasoning abilities. Gardner (1993) suggested skill in spatial ability determines how far one will progress in the sciences. There is no consensus as to the number of distinct spatial abilities that exist. The two most commonly agreed upon categories are *mental rotation* and *visualization*. A third category is usually *perception*, although some sources name *orientation* as the third category (Hegarty & Waller, 2004; Kaufmann, Steinbugl, Dunser & Glueck, 2003). Bodner and Guay (1997) portray *orientation* and *visualization* as the two major categories as the result of factor analysis of various tests used to measure spatial ability.

Spatial Ability Development

Several studies indicate that spatial ability can be improved if training with appropriate materials is provided (Cohen et al., 2003; Kinsey, 2003; Newcomer et al., 1999; Potter & van der Merwe, 2001). Kinsey (2003) found that when university freshmen identified as at risk participated in a session on strategies to improve spatial ability skills, gender differences on the pretest were eliminated as a consequence of the instruction on spatial strategy (Kinsey, 2003). Cohen et al. (2003) found that it is possible to train participants to use mental rotation and perspective by modeling these spatial strategies with animation (Steinke, Huk & Floto, 2003). In another study, students with low spatial ability spent significantly more time viewing high quality videos and 3-D animations than did students who had high spatial ability (Steinke et al., 2003).

Not all studies indicate that the use of computer software is a significant factor in improving spatial abilities. In a study using 2-D and section models, no difference was found between active and passive controls. Shavalier (2004) investigated whether CADD-like software called *Virtus Walk Through Pro* could be used to enhance spatial abilities of middle school students. No significant difference was found between the control and treatment groups, and no treatment effects were found in measures related to gender or spatial ability levels.

Relationship of Spatial Ability to Mathematical Ability

Mathematical concepts and relationships are often intangible and are therefore difficult to teach. A relationship has been shown between spatial and mathematical ability, and some indicators suggest spatial ability is important for achievement in science and problem solving (Grandin, Peterson & Shaw, 1998; Keller et al., 2002). Yet, there is little emphasis in the educational system on the development of spatial abilities, perhaps because such abilities are taken for granted or believed to be innate.

Relationship of Spatial Ability to Gender and Ethnicity

Previous studies indicate a possible relationship between gender and spatial visualization ability (Alias, Black & Gray, 2002). Some studies indicate that males perform better on spatial rotation tests, but not necessarily on other aspects of spatial ability (Grandin et al., 1998; Santacreu, 2004). Bodner and Guay (1997) stated that gender differences often account for only negligible fractions of the variance in spatial ability (Bodner & Guay, 1997). Although the largest difference was in mental rotation, tests of visualization factors show differences between genders are small or null (Burin, Delgado & Prieto, 2000). Indeed, meta-analyses reveal that biological factors account for no more than five percent of the variability in spatial performance (Schultz et al., 2003). Several studies found that gender was not related to various aspects of spatial ability (Postma, Izendoorn & De Haan, 1998; Voyer, 1998) while Hubona and Shirah (2004) found relationships between gender and various aspects of spatial ability.

Ritz (2004) found that disparities exist from ethnicity and socioeconomic factors. The largest disparity between African Americans and white students in grade eight is measurement. The gap increased from 40 points in 1990 to 58 points in 2000. A similar gap exists when comparing whites and Latinos (Ritz, 2004).

Background and Significance

Most ninth grade students in Mississippi take a modular Technology Discovery course that includes a computer-aided design and drafting (CADD) module. A characteristic of 3-D CADD modeling is the manipulation of geometric shapes using spatial ability. In order to implement 3-dimensional software in curricula statewide, *Pro/Desktop*® (2003) was made available through the *Design and Technology in Schools Program* sponsored by the Parametric Technology Corporation. Evidence did not exist about the effectiveness of using 3-dimensional CADD programs to develop spatial ability. This study investigated whether selected instructional methods using 3-dimensional CADD software had an effect on the development of spatial abilities of ninth grade Technology Discovery students.

Purpose and Research Questions

The purpose of this study was to determine if there was a difference in the development of the spatial abilities of Mississippi ninth grade Technology Discovery students by instructional treatment as measured by the Purdue Visualization of Rotations Test (PVRT) (Bodner & Guay, 1997). The research questions were:

1. What are selected characteristics of Technology Discovery students? The characteristics included were gender, ethnicity, co-registration in art, and co-registration in geometry.
2. Do differences exist in the spatial ability development of Technology Discovery students when they are taught using various methods (treatments), when the spatial ability pretest scores are controlled?
3. Do differences exist in the spatial ability development of Technology Discovery students when they are taught using various methods (treatments), when the spatial ability pretest scores, gender, ethnicity, co-registration in art, and co-registration in geometry are controlled?

Method

A quasi-experimental design was used for this study. Intact ninth grade Technology Discovery classes were used, with teachers using *Pro/Desktop*® 3-D CADD software in a modular setting. The dependent variable was spatial ability as measured by the PVRT. The experimental treatments were as follows:

> *Teacher and Module (Experimental).* This group was taught by the teacher using researcher-developed lesson plans and 3-D CADD modeling software during the design unit, followed by module rotations in which pairs of students used researcher developed, student-directed material to learn more about the 3-D CADD modeling software. Both teacher-directed and student-directed lessons used 3-D physical models as an aid to instruction.
>
> *Module Only (Experimental).* This group was taught spatial ability using 3-D CADD modeling software without teacher-directed lessons. Instruction occurred only during module rotations in which pairs of students used researcher developed, student-directed curriculum material in conjunction with 3-D CADD modeling software to develop spatial ability. The lessons utilized 3-D physical models as an aid to instruction.
>
> *Existing Material (Experimental).* This group was taught spatial ability using 3-dimensional CADD modeling software during module rotations in which pairs of students used the methods and materials that had previously been used by that teacher, with no interventions or changes. It should be noted that a wide variety of materials existed.
>
> *No CADD Instruction (Control).* This group was not enrolled in Technology Discovery classes and the schools did not offer CADD.

Population and Sample

Schools that operated on a 4x4 block schedule and offered Technology Discovery were included in the 3 treatment groups. Students in these schools completed the Technology Discovery course during one semester, with class periods of at least 94 minutes per day. Participating schools with intact classes provided cluster samples. Block schedule schools typically operated three classes per day. Technology Discovery was designed for a maximum class size of 24 students. Each teacher assigned student pairs to instructional module rotations at the beginning of the school year. Each class had the potential of having 12 rotations with two students per rotation.

To avoid researcher bias, schools (with their teachers and students) were randomly assigned to one of three experimental treatments (instructional methods). Teachers located in the same schools were assigned to the same instructional method. The design used a control group from schools not offering CADD. To facilitate consistency, teachers participating in the study received oral and written instructions about study procedures. They were contacted at least two times by telephone and email prior to beginning the study. Instructional materials, tests, information forms, instructions for test administration, and return envelopes were mailed. Standard consent forms were used to obtain consent from parents or guardians for the students to participate in the study. Table 1 summarizes the instructions provided to each teacher. Usable data were obtained from 464 students by instructional method, as follows: Teacher Instruction with Module – 101 (21.8%), Module Alone - 164 (35.3%), Existing Materials – 116 (25.0%), and No CADD Instruction (Control Group) – 83 (17.9%).

Table 1
Instructions provided to technology discovery teachers participating in the study.

	Instructions Provided to Teachers		
Treatment	**Test administration, submission of data**	**3-D student module material, use of physical models**	**Teacher centered instruction**
1 - Teacher with module	Yes	Yes	Yes
2 - Module alone	Yes	Yes	No
3 - Existing materials	Yes	No	No
4 - No CADD	Yes	No	No

Note. Verbal and written instructions were provided to each teacher.

Treatment Development

Lesson plans and instructional material were developed by the researcher. The researcher is a certified *Pro/Desktop*® trainer and highly qualified to develop material for the software. Instructional sessions were developed using PowerPoint. An existing instructional tutorial for *Pro/Desktop*® CADD software was utilized in the final lesson.

The instructional materials incorporated the recommendations by Kinsey (2003) regarding the need to provide a combination of methods, including 3-D physical models, observation, and hands-on computer use while learning to use CADD software. The design also incorporated the recommendations by Roschelle, Pea, Hoadley, Gordin, and Means (2001) who stated computer technologies should enhance student learning when the four factors of active engagement, participation in groups, frequent interaction and feedback, and connections to real-world contexts are kept in mind while designing instruction. Lesson plans for 160 minutes of teacher-directed instruction supported by physical models were designed. The physical models were then located at the CADD workstation for student use with the instructional module. Module materials for learning the CADD software and physical models were prepared to support instruction for both the *Teacher and Module* and *Module Alone* instructional methods (1 and 2). Student material included rotation of the objects being modeled on the computer. The connection between geometry and engineering drawing (Keller et al., 2002; Lowrie, 1994; Smith, 2001) led to the inclusion of a review of basic geometric shapes and terms in the modular instructional materials. The student-directed modular instructional material was developed for approximately 450 minutes of modular instructional time. Both instructional methods 1 and 2 used this material.

Five teachers who were certified as *Pro/Desktop*® trainers reviewed the material for face validity. These teachers suggested improvements to the physical models and revisions to the PowerPoint presentation, including wording and the order of the module sessions. These revisions were made prior to dissemination of the materials. The *Existing Materials* treatment group (3) was instructed to continue to use materials that were in use during the 2004-2005 school year. These consisted of tutorials utilized in the training of teachers. The *No CADD Instruction* treatment group (4) used no software and did not study CADD.

Data Collection and Analysis

Teachers administered the PVRT as a pretest to all Technology Discovery students in their classes near the beginning of the semester, along with a student information sheet that gathered data on gender, ethnicity, and whether they were currently enrolled in art or geometry. The posttest was given 5-7 school days after each student completed the CADD module rotation. The time between module and posttest was chosen to measure student achievement at a consistent amount of time after instruction.

The PVRT was used for both the pretest and posttest. It is appropriate for use with adolescents and may be administered either in groups or individually. This test is among the spatial tests least likely to be confounded by analytic processing strategies (Bodner & Guay, 1997). The test measured the ability to visualize the rotation of 3-dimensional objects. The instrument was chosen because of its high correlation with similar instruments measuring visualization that were not cost effective to use. The PVRT instrument included 30 questions in which an object was pictured in one position, and then it was shown in a second image, rotated to a different position. Participants were shown a second object and given five choices, one of which matched the rotation of the example object. They were asked to select the object that showed the same rotation as the example for that question. Students had 15 minutes to complete the timed test. Reliability for the PVRT reported by Bodner and Guay (1997) using KR-20 and split half reliability coefficients ranged from .78 to .85 in nine studies that involved samples sizes ranging from 127 to 1,648.

Teachers assigned students to rotation schedules at the beginning of the semester, using methods prescribed during teacher training for Technology Discovery. They were asked to adjust the rotations to ensure that no other CADD or Spatial Information Technology module was completed prior to the module under investigation, nor in the week prior to the posttest. Other than the adjustment stated above, their usual assignment procedures for rotations were applied.

Students in the control group (No CADD group) took the PVRT test with a five-week interval between pretest and posttest. Schools in the control group administered the test in ninth grade English I classes in order to provide the module under investigation, nor in the week prior to the posttest. Other than the adjustment stated above, their usual assignment procedures for rotations were applied.

Students in the control group (No CADD group) took the PVRT test with a five-week interval between pretest and posttest. Schools in the control group administered the test in ninth grade English I classes in order to provide the appropriate equivalent sample population. English I classes were used because the course was required of all ninth grade students.

The *alpha* level was set *a priori* at .05. Descriptive statistics including values and percentages were used to analyze the data for Research Question 1. Analysis of covariance was used for Research Questions 2 and 3. The number of schools in the sample was 14, including 10 schools that offered Technology Discovery and 4 that did not.

Results

Characteristics of Population

Most of the students in the study were female and white. A higher number of female students were in each of the treatment groups. There were more black male and female students in the No CADD instruction treatment (control) group, and more white male and female students in the other three treatment groups (see Table 2).

Table 2
Ethnic background and gender reported by treatment group

		Ethnicity									
		Black		**White**		**Hispanic**		**Asian**		**Other**	
		n	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Teacher Instruction	**F**	16	29.2	35	63.6	1	1.8	2	3.6	1	1.8
& Module *n* = 101	**M**	4	7.9	41	89.1	0	0.0	0	0.0	1	2.2
Module Alone	**F**	25	27.8	62	68.9	1	1.1	0	0.0	2	2.2
***n* = 164**	**M**	19	25.7	52	70.3	2	2.7	0	0.0	1	1.3
Existing Materials	**F**	20	31.7	43	68.3	18	0.0	0	0.0	0	0.0
***n* = 116**	**M**	21	39.6	30	56.6	14	1.9	0	0.0	1	1.9
No CADD Instruction	**F**	26	56.5	18	39.1	0	0.0	1	2.2	1	2.2
(Control) *n* = 83	**M**	18	48.7	14	37.8	1	2.7	2	5.4	2	5.4
Total		149	32.1	295	63.6	6	1.3	5	1.1	9	1.9

There were 61 (13.1%) students enrolled in art, 48 (10.3%) enrolled in geometry, and 17 (3.4%) students enrolled in both art and geometry. The

Table 3
Participants co-enrolled in art and/or geometry by treatment group

	Treatment Group				
Courses	**Teacher Instruction and Module % (*n*)**	**Module Alone % (*n*)**	**Existing Materials % (*n*)**	**No CADD Instruction % (*n*)**	**Totals % (*N*)**
No Art or Geometry	52.5 (53)	81.2 (133)	81.0 (94)	71.1 (59)	73.0 (339)
Art	16.8 (17)	14.6 (24)	12.1 (14)	7.2 (6)	13.2 (61)
Geometry	23.8 (24)	2.4 (4)	6.0 (7)	15.7 (13)	10.3 (48)
Both Art Geom.	6.9 (7)	1.8 (3)	0.9 (1)	6.0 (5)	3.5 (16)
Total	100.0 (101)	100.0 (164)	100.0 (116)	100.0 (83)	100.0 (464)

Differences in Spatial Ability Posttest Achievement with Pretest Covariate

Research Question 2 asked if differences existed in spatial ability test scores of Technology Discovery students as measured by the PVRT, when the pretest scores were controlled, and students were instructed using differing treatments (instructional methods). An analysis of covariance (ANCOVA) was conducted to determine if there was a difference in student achievement among the instructional methods. The independent variable of instructional treatment included the four levels described in the research question. The dependent variable was the posttest, the covariate was the pretest, and the fixed factor for the analysis was the instructional method.

The preliminary analysis using Levene's Test revealed that the variances in the posttest scores did not differ among the treatments ($F_{(3, 460)}=.71; p=.548$). Therefore, equal variance across treatment groups was assumed. In addition, a model lack-of-fit test was conducted to determine if there was evidence that the effects of the treatments were nonlinear. The non-significant results of the lack-of-fit test ($F_{(88, 368)} =1.25; p=.086$) indicated that the effects were likely linear. In addition, the interaction between the method factor and the pretest covariate was not significant, ($F_{(3, 456)} =1.83, p>.05$), indicating that the differences on the posttest among groups did not vary as a function of the covariate. Therefore, the pretest was an appropriate covariate in the analysis of covariance.

Significant differences existed among the means by instructional method ($F_{(3,459)} =6.6, p<.001$, partial eta^2=.04) (see Table 4). According to Green and Salkind (2003) the partial eta^2 level of .09 indicates a moderate relationship between posttest scores and teaching methods, with pretest scores as the covariate. Table 5 presents the unadjusted and adjusted means of posttest scores for each instructional method and the control group with the covariate included. The adjusted mean for the Teacher Instruction and the Module groups is larger than the adjusted means for the other instructional treatment groups and the control group. The pairwise comparison conducted using the Bonferroni procedure revealed that the test scores for the Teacher Instruction and Module group were significantly higher than the other three groups.

Table 4.
ANCOVA test for differences among treatment means with pretest covariate

Source	***SS***	***df***	***MS***	***F***	***p***	**Partial *eta*^{2}**
Corrected Model	9317.53	4	2329.38	141.59	<.001	.55
Intercept	76170.31	1	76170.31	4630.04	<.001	.91
Instructional Method	741.58	3	247.19	15.03	<.001	.09
Pretest	8575.95	1	8575.95	521.29	<.001	.53
Error	7551.16	459	16.45			
Total	93039.00	464				
Corrected Total	16868.69	463				

Note. R^2 = .55 (Adjusted R^2 = .55).

Differences in Spatial Ability Posttest Achievement with Multiple Covariates

Research Question 3 asked if differences existed by treatment (instructional method) in the spatial ability of Technology Discovery students as measured using the PVRT when spatial ability pretest scores are controlled, and explanatory factors of gender, ethnicity, co-registration in either art and/or geometry are added to the model. Analysis of covariance with simple contrasts for the explanatory factors was conducted to analyze the data for this research question. The dependent variable was the posttest score; the covariate was the pretest score, and additional explanatory factors were gender, ethnicity, co-enrollment in art, and co-enrollment in geometry. The fixed factor was the instructional treatment method. Gender was not significantly correlated to the dependent variable posttest scores; therefore, gender was not included in the analysis.

Table 5
Posttest unadjusted and adjusted mean student scores by instructional method with pretest covariate

Instructional Method	*n*	Unadjusted *M*	Unadjusted *SD*	Adjusted *M*	Adjusted *SD*
Teacher Instruction and Module	101	15.01	5.97	14.38[a]	.41
Module Alone	164	12.56	5.41	12.59[a]	.32
Existing Materials	116	11.37	5.87	12.30[a]	.39
No CADD Instruction	83	12.66	6.83	11.97[a]	.45
Totals	464				

[a]Covariate in the model is evaluated with pretest value of 11.49.

An analysis was conducted to determine if the variances in the posttest scores were equal among the treatment groups when the fixed factors were included. The non-significant Levene's Test ($F_{(3, 460)}$ =1.11; p=.344) suggests that the variance of the postest scores was approximately equal for the four treatment groups, and equal variance across treatment groups was assumed. A model lack of fit analysis was conducted and it was not significant ($F_{(212, 288)}$ 1.02; p=.433).

An initial ANCOVA tested for the interaction effects. The interaction between the dependent variable posttest and covariate pretest was not significant. Interaction between the dependent variable posttest and ethnicity was not significant, nor was interaction between posttest and co-enrollment in either art or geometry. Since no significant interactions existed, the interaction effects were removed from the ANCOVA prior to conducting the final analysis. Table 6 reports the final analysis of covariance. This analysis resulted in a significant outcome for instructional method ($F_{(3,455)}$ =15.02, $p < .001$). The strength of the differences between the fixed factor instructional method and the dependent variable posttest was moderate as indicated by a partial eta^2 of .09 (Green & Salkind, 2003). It is interesting to note that the partial eta^2 in this analysis was the same as the result presented for research question 2.

Table 7 presents the unadjusted and adjusted means of posttest scores for each instructional treatment and the control group. The adjusted mean for the Teacher Instruction and Module group is larger than the adjusted means for each of the other instructional treatment groups and also larger than the control group. In order to determine whether the difference in means was statistically significant, further analysis using the Bonferroni *post hoc* procedure was conducted which confirmed that the mean scores for students in the Teacher Instruction and Module group were significantly higher than the other three groups.

Table 6.
Analysis of Covariance for Differences among Posttests by Instructional Method Groups with Pretest Covariate and Explanatory Factors

Source	SS	*df*	*MS*	*F*	*p*	*eta*^{2}
Pretest	8575.95	1	8575.95	521.10	<.001	.53
Method	741.58	3	247.19	15.02	<.001	.09
Ethnicity-white	27.07	1	27.07	1.65	.200	<.01
Ethnicity-black	8.83	1	8.83	.54	.464	<.01
Co-enrollment in Art	13.91	1	13.91	.85	.358	<.01
Co-enrollment in Geometry	3.25	1	13.25	.81	.370	<.01
Error	7488.11	455	16.46			
Total	93039.00	464				

R^2 = .56 (Adjusted R^2 =.55).

Conclusions and Discussion

In this sample, less than 30% of Technology Discovery students are black; fewer than 5% are Hispanic, Asian, or other ethnic backgrounds; and nearly 70%, are white. Since Mississippi public schools average slightly more than 50% black students enrolled statewide, the fact that less than 30% of the students in the classes were black is unusual. Over half of the Technology Discovery students are female. Both black and white females outnumber black and white males in the classes. Few Technology Discovery students enrolled in art or geometry.

Table 7
Posttest Unadjusted and Adjusted Mean Scores of Students by Instructional Method

		Unadjusted		Adjusted	
Instructional Method	***n***	***M***	***SD***	***M***	***SE***
Teacher Instruction & Module	101	15.01	5.97	14.19[a]	.42
Module Alone	164	12.55	5.41	12.61[a]	.32
Existing Materials	116	11.37	5.87	12.34[a]	.38
No CADD Instruction	83	12.66	6.83	12.20[a]	.46
Totals	464	12.81	6.04		

[a]Covariates appearing in the model are evaluated at the following values: pretest = 11.49, Ethnicity-White = .64, Ethnicity-Black = .32, Geometry Class = .14, Art Class = .17.

A difference exists in spatial ability based on the method used to instruct students using 3-D CADD modeling software, with the instructional method of Teacher with Module being more effective than either the Module Alone or the Existing Materials method in improving spatial ability achievement scores. This occurred both in the analysis for Research Question 2, where the only covariate was the pretest, and in Research Question 3, where gender, ethnicity, co-enrollment in art and co-enrollment in geometry were included as covariates. It can be concluded that the use of 3-dimensional CADD modeling software affects student spatial ability development when a combination of teacher-lead and student-directed instruction is used with 3-dimensional physical models.

The teacher-led lesson was the likely factor explaining the Teacher with Module group's gain in spatial ability. Roschelle et al. (2001) stated that social contexts such as teacher-directed group lessons give students the opportunity to successfully perform more complex skills than they could manage alone. Working on a task with others not only provides opportunities to replicate what others are doing, but also to discuss the task and ideas involved.

No difference was found among the spatial ability of students who studied CADD using the Module Alone method, the Existing Materials method, and students who did not study CADD at all. This occurred both in the analysis for Research Question 2, where the only covariate was the pretest, and in Research Question 3, where gender, ethnicity, co-enrollment in art and co-enrollment in geometry were entered as covariates. The instructional methods Module Alone and Existing Materials were both based on self-directed student learning.

A cursory review of test scores indicated that some students appeared to gain in the ability to mentally rotate an object. Others showed little or no gain. There may be a connection between this and the study done by Battista (2002) which cited the theory of constructivism as a basis for instructional design for teaching mathematics. The theory proposes that to understand new ideas, students must personally construct meaning using their own knowledge and reasoning. Though student-directed modular learning is based on this theory, it was not supported by this study. Student use of modules was only effective in increasing the spatial ability to mentally rotate objects when the teacher established a common understanding of the views used in the software prior to modular instruction. Various factors may account for the lack of gain in the Module Alone and Existing Materials groups. Due to the typical teacher-centered learning environment with which students are familiar, they may not consider instruction that is student-directed to be as important as traditional instruction. Constructivist learning theory suggests that by reflecting on experiences, students construct their own understanding of the world. In order for students to learn in this manner, they must actively participate in the planned activities of a lesson. In a modular learning environment some students may not seriously concentrate on the lessons provided, considering themselves as passive learners responsible only for material that is presented by teachers for which they expect to be tested. Although multimedia has been relatively successful as a learning tool, it is not enough by itself to guarantee that students will actually learn. The exclusive use of multimedia is intriguing, but it does not necessarily require the learner to be in active control of the learning process or necessarily thinking about what is being presented (Mohler, 2001). In addition, if two students are working at a learning station and only one computer is available, one of the pair may dominate the interaction with the software. The passive student may not take responsibility for her or his learning, allowing a partner to interact more with the software. When students are placed in the relatively passive role of receiving information, they often fail to develop sufficient understanding to be able to apply what they have learned to other situations (Roschelle et al, 2001).

Moreover, hands-on manipulations may divert the short-term memory resources of some students, reducing the possibility of comprehending the simultaneous manipulation of a larger number of mental elements (Smith, 2001). In addition, Steinke et al. (2003) found that some students required observation with no activity in order to process new concepts.

Recommendations for Future Research

Based on the findings of this study and the review of literature, one can conclude that little is known about how the use of Computer Aided Design and Drafting technology affects student spatial ability development. Continued research in this area is both vital and needed. Replication of this study in other states would contribute to the research and knowledge base for both CADD instruction and spatial ability improvement. Further research is needed to determine whether the conclusions reached in this study would be consistent with other similar studies and, specifically, whether or not a particular instructional method using 3-D CADD modeling is consistent in the improvement of the spatial ability of students. This would contribute to the goal of the National Research Council (2006) to include an emphasis on learning to think spatially in education systems.

Numerous studies indicate a high correlation between mathematics achievement and spatial ability. Other studies have found that spatial ability affects student achievement in science as well as other subjects. Therefore, research that specifically examines development of spatial ability when using 3-D modeling software should be continued. It is possible that the development of spatial visualization ability could be the most important contribution that technology education could make to learners. Consequently, it could be the most defensible reason for the inclusion of technology education for all students.

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Delivering Core Engineering Concepts to Secondary Level Students

Chris Merrill, Rodney L. Custer, Jenny Daugherty, Martin Westrick, and Yong Zeng

Introduction

Within primary and secondary school technology education, engineering has been proposed as an avenue to bring about technological literacy (Lewis, 2005; Dearing & Daugherty, 2004). Different initiatives such as curriculum development projects (i.e., Project ProBase and Project Lead The Way) and National Science Foundation funded projects such as the National Center for Engineering and Technology Education (NCETE) have been developed to infuse engineering into primary and secondary education. For example, one key goal of the technology teacher education component of NCETE is to impact the focus and content of the technology education field at the secondary level (National Center for Engineering and Technology Education, 2005). More specifically, the goal is to facilitate students' learning relative to core engineering principles, concepts, and ideas. A number of activities have been developed by the Center to facilitate these goals, including a series of teacher professional development experiences, research designed to identify core engineering concepts, development of engineering-related activities, engagement with faculty from the STEM disciplines, and interaction with technology education pre-service teachers.

Through the efforts of NCETE, three core engineering concepts within the realm of engineering design have emerged as crucial areas of need within secondary level technology education. These concepts are *c*onstraints, *o*ptimization, and *p*redictive *a*nalysis (COPA). COPA appears to be at the core

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of the conceptual knowledge needed for students to understand and be able to do engineering design.

One of NCETE's five technology teacher professional development institutions (Illinois State University) has focused exclusively on the delivery of these COPA concepts. These concepts have emerged as distinctly important, based on analysis of multiple engineering design processes and the technological design and problem solving process. At Illinois State University, two cohorts of practicing and pre-service technology teachers have engaged in professional development workshops to become better prepared to deliver engineering concepts to their students. The three core engineering concepts, mentioned earlier, were identified: constraints, optimization, and predictive analysis. These were selected based on over three consecutive years of professional development experiences with teachers, partnerships with the engineering community, hands-on activities, and an analysis of related research. The review of prior research concentrated primarily on the nature of engineering and engineering design, how it differs from technology education processes, and the necessary conceptual and procedural knowledge.

Empirical knowledge is needed to better understand how to increase student learning of COPA. This study sought to provide that knowledge using a NCETE cohort of practicing and pre-service technology teachers who designed and developed a unit of instruction to deliver these three core engineering concepts to secondary level technology education students. Using a mixed method quasi-experimental, pretest, post-test, no control group design, this study explored the extent to which students understood and were able to demonstrate an understanding of constraints, optimization, and predictive analysis. It is believed that through this strong conceptual base, a better understanding of engineering and engineering design can be achieved.

Review of the Literature

Predictive Analysis

In a review of science, engineering and technology careers, Deal (1994) stated that engineers apply mathematical and scientific principles to solve problems. The introduction of these tools into the analytical stage of the design process represents an indispensable part of engineering design (Harris, & Jacobs, 1995). Eekels (1995) observed how the prediction component functions in the engineering design process, noting that "if the conditional prediction sounds unfavorable, then we generally simply abstain from that action and design another action," (p. 176) which is to make the informed decision before constructing the prototype of a design. Hayes (1989) observed that predictive analysis is carried out in the planning environment, not the task environment, with several distinct advantages: (a) moves made in the planning environment can be easily undone while task environment actions cannot be reversed; (b) predictive analysis is relatively inexpensive; and (c) it permits design flexibility.

"The process of thinking before acting" is critical if designing is to be a predictive rather than a trial-and-error process (Hayes, 1989). Trial-and-error remains the prevailing approach to design in technology education classrooms, where analytical mathematical tools are frequently not used to design and prototype design ideas (Lewis, 1999; Merrill, 2001). Lewis (2005) argued that conceptual design is within the normal purview of technology education and that science and mathematics should be taught to help students make predictions about the design through the process of analytical design. The *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association, 2000) reinforce the systematic aspects of predictive analysis. "Because so many different designs and approaches exist to solving a problem, a designer is required to be systematic or else face the prospect of wandering endlessly in search of a solution" (International Technology Education Association, 2000, p. 91).

Constraints

The design processes utilized in engineering and technology education are very similar with some notable exceptions. Lewis (2005) has suggested that engineering design places more emphasis on assessing constraints, trade-offs, and utilizing predictive analysis compared to technology education. The importance of constraints is, however, included in the *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association, 2000). In Standard Eight, constraints are viewed as an integral part of an iterative process that typically requires students to consider costs, economics, feasibility, time, material, and environmental implications. Students should be able to assess and incorporate constraints into design activities.

Addressing constraints early in the problem identification stage may assist students in developing viable solutions, since this process helps reduce the size of the solution space (Jin & Chusilp, 2006). Expert designers typically move quickly from defining the problem (problem space) to the solution space by assessing the constraints to the problem and searching for contextually related problems that they have solved in the past (Cross, 2002; Cross, 2004; Middleton, 2005). This is similar to a model revised by Middleton, where the problem space is defined as the problem state, goal state, and search state. Middleton's "search state" can be viewed as identifying the constraints; while iteratively moving between the problem state and goal state, and concurrently decomposing an ill-defined problem into well-defined sub-problems (Cross, 2002; Ho, 2001).

Optimization

Design optimization extends beyond simply producing a design that adheres to a defined set of constraints or criteria. The purpose of optimization is to achieve the "best" design relative to a set of prioritized criteria or constraints. These include maximizing factors such as productivity, strength, reliability, longevity, efficiency, and utilization. Engineers must make many technological and managerial decisions during the design process in order to produce the best design. The ultimate goal of all such decisions is to minimize undesirable effects, while maximizing desirable effects, producing a "better, more efficient, less expensive solution that is in harmony with the laws of man and nature" (Ertas & Jones, 1993).

Optimization typically occurs during the formulation of a design problem. According to Arora (1989), formulation of a problem requires approximately 50% of the total effort needed to solve it. Optimization techniques provide well-defined procedures to aid the designer in correctly formulating the problem. For example, Statnikov (1999) outlined three questions that designers should be able to answer when formulating a design problem:

1. What to search for? (resulting in identifying the performance criteria.)
2. Where to search? (resulting in defining all the constraints imposed on the design, which produces a set of feasible solutions.)
3. How to search? (resulting in identifying the optimization technique that is most suited for the specific features of the problem being solved.)

Formulating a design problem to achieve an optimal solution often involves transcribing a verbal description of the problem into a well-defined mathematical statement. This process enables the designer to search for the optimal design according to the identified performance criteria. Optimization methods frequently use mathematical concepts such as vector and matrix algebra, and calculus to analyze and optimize variables. As Arora (1989) pointed out, "the importance of proper formulation of a design optimization problem must be clearly understood because the optimum solution will only be as good as the formulation is" (p. 21).

Purpose and Research Questions

The purpose of this study was to assess the effectiveness of a unit of instruction in teaching core engineering concepts to secondary level technology education students. The following research questions guided the study.

1. What type of engineering design activities and lessons will effectively deliver selected core engineering concepts to technology education students at the 10-12 grade level?
2. Is there a relationship between performance in mathematics courses taken prior to participating in the unit of instruction and post-test instructional gain?
3. Is there a relationship between performance in physical science courses taken prior to participating in the unit of instruction and post-test instructional gain?

Methodology

Research Design

This study used a mixed methods quasi-experimental, pre-test post-test, no control group design, with the treatment as the independent variable and pretest-posttest as dependent variables. The participants in this study received a pre-test, treatment, and a post-test. The researchers chose not to use a control group in this study for several reasons. First, since the data were gathered at multiple high school locations, it would have been extremely difficult to apply a uniform control group experience across all schools (i.e., each school's typical technology education curricula are different). Second, the logistics of identifying sufficient numbers of like courses taught by the same professionally developed teachers were problematic. While a control group design would have strengthened the study, the decision was made to proceed with a pre-test, post-test design augmented by a qualitative component, given the exploratory nature of the research. Additionally, after the posttest, focus groups with randomly selected participants were conducted to "stimulate embellished descriptions" (Fontana & Frey, 2005, p. 704) of the 20-class session unit of instruction.

Treatment

During the 2005-2006 school year, each technology education teacher who was involved in this study, as well as one mathematics and one science teacher, completed 120 hours of professional development related to infusing engineering concepts into high school technology education. During this professional development, the eight technology education, one mathematics, and one science teacher helped to develop the 20-class session unit of instruction and the activities that supported infusing engineering concepts into the curriculum. These teachers were chosen because they were already participating in the NCETE professional development from which the study emerged. In addition, these teachers helped to solidify the treatment fidelity because they were key researchers in the development and delivery of the unit of instruction.

The unit of instruction included four lessons, with specific content and activities. Although the units of instruction include activities that may seem similar to previously published curricula, the teachers developed the units of instruction independent of established materials because the focus of the units of instruction was on constraints, optimization, and predictive analysis. Other than the first lesson and activity (see below), teachers were permitted to teach the remaining lessons in any order. The unit of instruction was scheduled to be completed in 20 class sessions. Some of the teachers completed the unit prior to the 20 days, while other teachers went beyond the targeted number of days. Each lesson had a student version and teacher version. The teacher version of each lesson included supplemental materials, including presentation materials specifically designed to address the key concepts being delivered in the unit. Grading rubrics were provided to the teachers and students for each lesson. Below is a description of each lesson and activity.

The first lesson and activity (treatment) that the students (research participants) completed during this study to introduce COPA was called "Volume Barge." In this lesson and activity, students were challenged to design and create a barge-type artifact made from one piece of 8.5” x 11” laminated card stock capable of holding the most weight before sinking; the barge had to be a rectangular shape. Students used volume calculations to optimize the best design based on the constraints. In a competitive style format, students graphed, using Microsoft Excel, the entire class performance to determine the winner. Using calculus based concepts, an optimum volume value was established, which set the standard for optimizing the design. This lesson/activity was deemed the favorite by most of the students from the eight schools, largely due to its competitive nature.

A second lesson and activity the students completed was related to energy efficiency. During this lesson, students used mathematical formulas and existing data to determine R and U values for insulated wall cavities. Each group of students was provided with four completed wall sections, each having a 12” x 12” opening constructed with 2” x 4” and 2” x 6” framing materials. Three of the wall cavities were filled with different insulating materials, while the fourth section was left empty. The students were challenged to calculate the efficiency versus cost in a life-cycle approach, to determine the most optimal choice for insulation based on an average daily temperature and cost per thermal unit. Each completed wall section (four in all to create a square) was covered with a sheet of plywood, and a 100 watt incandescent lamp was placed in the center. Using an infrared heat-sensing device, the students were able to determine insulation efficiency. From the experiences learned from this activity, the students had to use predictive analysis to optimize the life cycle costs of construction and building ownership over 5, 10, 15, and 25 year periods for a 2000 square foot structure. Students used Microsoft Excel to graph their results and present them to the class. This lesson and activity was classified as the second favorite of most of the students from the eight schools, largely because it involved a hands-on experience.

The third lesson and activity the students completed utilized a pre-fabricated golf ball launching device made from PVC and wood framing materials. Students used predictive analysis techniques to accurately launch a golf ball from a specific height and angle to a specific end distance. Students had to understand vectors, laws of motion, and energy to succeed. Students first predicted (non-analytic) how far the golf ball would travel and then used mathematical formulas to analyze how and where the ball would travel. In addition, students quickly learned that there exists an efficiency factor and that no machine or mechanism is 100% efficient. Students graphed their results and presented their findings to the class. This lesson and activity was rated as the third favorite by most of the students from the eight schools involved in this study, largely because the students could see the mathematical calculations in action in observing where the ball should and would land.

The fourth lesson and activity the students completed dealt with identifying where and how mechanical energy is used and lost in their school. As an introductory activity to this lesson, students were provided with four different types of light (incandescent, fluorescent, halogen, and LED) to examine their efficiency. After classroom discussion regarding the cost, life-span, and energy used from these different sources of light, students became engaged in an activity in which they had to locate four different sources of mechanical energy in their school to determine their efficiency. Students created a proposal that outlined where mechanical energy is being lost throughout their school and how they would use the wasted energy to complete productive work in other applications. Students used Newton scales, stop watches, and tape measures to determine mechanical energy (i.e., force, distance, and time). Each potential solution that students determined also included a wattage factor. During the presentation, students discussed their data collection methods, design solutions, the constraints associated with each design solution, and how each design would be optimized. Overall, students enjoyed this lesson and activity, but felt because it lacked a hands-on (building) approach, their engagement was not as high.

Instrumentation

The research team and a technology education teacher, who has a mechanical engineering degree, developed the test instrument used in this study. The development of the test instrument was guided by a review of the literature related to the engineering concepts: constraints, optimization, and predictive analysis. The thirty-item test instrument was developed to target the three concepts across three levels of Bloom's taxonomy. For the purpose of this study, Bloom's framework was reduced to three levels: comprehension, application, and analysis/synthesis. Comprehension included Bloom's Knowledge and Comprehension categories, application included Bloom's Application category, and analysis/synthesis combined Bloom's Analysis, Synthesis, and Evaluation categories (Dalton, & Smith, 1986). For example, questions written at the comprehension level used verbs offered by Dalton and Smith, including explain, predict, or discuss.

Ten items were developed to target each of the three engineering concepts and were spread relatively evenly across the three levels of Bloom's taxonomy. At the comprehension level there were four constraint, four optimization, and four predictive analysis questions. At the application level there were three constraint, three optimization, and three predictive analysis questions. At the analysis/synthesis level there were three constraint, three optimization, and three predictive analysis questions.

The instrument was subjected to three revision cycles before a final version was established. The first cycle consisted of an internal review by the researchers. The second cycle consisted of a pilot test that was administered to a cohort of practicing technology education teachers during the summer professional development experience. This was done to determine whether the instrument was at the appropriate level of difficulty for secondary students and to identify any problematic questions. Their estimates were based on many years of experience of working with secondary level students. The research team and the technology education teacher then later refined potentially problematic questions. The third cycle consisted of an expert panel review where content validity was verified by sending the instrument to a panel of engineering and technology education professors and practitioners. These individuals completed a review of the instrument and a survey asking whether the questions measured an understanding of the three concepts at the different levels. Based on the feedback from the expert review panel, the test was further refined by the research team. This process resulted in an instrument containing thirty items that were believed to be at the appropriate difficulty level that measured an understanding of COPA at the three different levels. The same instrument was used for both the pretest and posttest. The reliability of the test instrument using Cronbach's coefficient alpha was $r = .782$.

Sampling Procedures

A purposive sampling frame was utilized for this study, so the same teachers who developed the instructional materials were able to deliver the actual instruction in their classes to the study participants. Eight of the technology education teachers who participated in the NCETE professional development sessions at ISU recruited the students from their schools. Recruitment was conducted in nine intact technology education classes, since one teacher was able to recruit participants from two separate classes. Initially, 124 high school level technology education students agreed to participate in the study. However, as a result of attrition, only 114 ($n = 114$) students remained in the study at the time of the posttest. Within the final population there were 102 male and 12 female students.

In order to assess if there were significant differences between the subjects who remained in the study and those who did not, a one-way ANOVA at the a =.05 level was conducted using the pre-test scores as the dependent variable. The results suggested that there were not significant differences between the two groups in terms of test scores $F(1,123) = .04$, $p > .05$. Table 1 illustrates the grade level and number of research subjects (students) per grade level involved in this study. It should be noted that all high school teachers and students were from Illinois schools.

Table 1
Grade level of participants

	f	**Percent**
9th Grade	14	12.4
10th Grade	17	15.0
11th Grade	48	42.5
12th Grade	34	30.1

$n = 114$

Current or previous mathematics course involvement of students in the sample included 72% in Algebra I, 63% in Algebra II, 71% in Geometry, 46% in Trigonometry, 34% in Pre-Calculus, and 6% in Calculus. The breakdown of science classes completed or that were presently being taken by the high school students was 47% in General Science, 76% in Biology, 57% in Chemistry, and 36% in Physics.

Focus Groups

A formal, directive, structured focus group was deemed most appropriate for this study (Fontana & Frey, 2005). As Morgan (2002) argued, by systematically approaching the focus group interviews a methodological continuity is created so as to better assess the outcomes. Within twenty-four hours after completing the posttest, a focus group of systematic selection procedure was used to identify students from the eight high schools who participated in the study. Using the alphabetized course roster for each of the nine classes, every third student was selected to potentially participate in focus group. However, if that student did not wish to participate or had not submitted a consent form, that student was not selected for the sample. In a few cases, every third student resulted in a sample size of less than six, so two cycles of every third student, beginning with the last student selected, was conducted. For one school, the class size was small enough to conduct a focus group with all of the students. For two other schools, only a few students submitted consent forms or agreed to participate in the focus group, so all of those students participated in the focus group. A total of nine students from each school were selected to participate in the focus groups. The first six students selected were targeted as the primary participants, and three students were selected as alternates in case of absences or withdrawals. A total of eight schools and nine separate classes were involved with the focus group (n = 54). Of the 54 students selected for the focus groups, 47 were males, 7 were females.

Each focus group, lasting no longer than forty-five minutes, was guided by a script of fifteen questions that were divided into three categories: appeal questions, probing questions, and suggestions for improving the unit of instruction. Each focus group was conducted by two members of the research team. One of the researchers asked the questions and the other researcher acted as the scribe. In some cases, both the interviewer and scribe asked the students questions. Each focus group session was digitally recorded and saved as an MP3 file. Each of the researchers independently listened to each focus group session and developed synthesis paragraphs.

Procedures

This study was conducted in two phases. Phase One was the development of the 20-class session unit of instruction to be delivered to high school level technology education students. Phase Two consisted of delivering and assessing the unit of instruction with the participants of this study. Phase One began during the Summer 2006 technology education session at ISU. Twelve high school level technology education teachers attended a five-day professional development session to develop the unit of instruction to integrate COPA in their technology education courses. Some of the teachers in this experience had attended ISU's professional development sessions the previous year. Those sessions were also focused on integrating engineering concepts into high school level technology education curricula.

During the first two days of the summer 2006 session, the teachers participated in presentations by technology education faculty members from ISU, an engineering professor from the University of Illinois at Urbana-Champaign (UIUC), NCETE doctoral fellows from UIUC; and science, mathematics, and technology education teachers from the public high school system. These presentations included a review of COPA, Wiggins and McTighe's backward design process (Wiggins, & McTighe, 2005), and activities that emphasized the COPA concepts.

During the third and fourth day of the workshop, the teachers working in groups of four developed the unit of instruction using the backward design process (Wiggins & McTighe, 2005). As discussed in the instruction development section, each group of teachers developed artifacts for each of the different activities. Concurrently, the NCETE doctoral fellows, in conjunction with the technology education teacher from the high school system, began developing the test instrument to assess students understanding of COPA.

On day five, the initial instrument was pilot tested with the high school teachers and scored. The results were shared with the teachers in order to obtain feedback regarding content and construct validity, and appropriate floor and ceiling height for high school level students. Additionally, the groups of teachers presented their activities to the session participants in order to obtain feedback that could be used to later enhance the activities. After the conclusion of the experience, the eight teachers who would actually be able to deliver the unit of instruction were asked to continue with the refinement and final development of the activities.

Between August and October, final lessons and activities related to Phase One were completed: (a) Institutional Review Board protocol approval was obtained from ISU and the UIUC, as well as from the individual high schools, (b) the test instrument was further refined after obtaining feedback from engineers, technology education professors, and practicing teachers, and (c) the eight teachers returned to ISU on October 5, 2006 for a one-day session to deliver the finalized units of instruction to the participating teachers involved in the study in order to receive formative feedback. Additionally during this time, technology education pre-service teachers enrolled at ISU began constructing the artifacts that were needed for the activities and pre-assembled these into kits that were sent to the participating high schools. The use of pre-assembled kits was deemed necessary in order to maintain treatment fidelity by making certain that all sites were using identical materials. In addition to uniformity provided by the pre-assembled kits, the process reduced the total time required to implement the study. This time element was an important factor, since teachers were injecting the research unit into their regular semester's curriculum.

Phase Two began during the first week of October 2006. Since the high school students were under 18, both parental consent and student assent were required. The technology education teachers distributed the appropriate forms to the participants, signatures were obtained, and the forms were returned to their teachers who then forwarded the forms to the research team. The participants were then administered the pre-test that consisted of the 30 items related to measuring COPA at the three, Bloom-based levels of understanding.

The delivery of the unit instruction by the teachers began between the second and third week of October 2006. Because the teachers were working within the limitations of their existing curriculum, it was not feasible for all sites to begin delivery of the unit of instruction on the same day. The unit of instruction was delivered over the span of 20 class sessions. Immediately following the conclusion of the last class session, the posttest was administered to the participants and returned to the research team. As previously noted, the pretest and post-test were identical.

Findings and Discussion

Consistent with the mixed model research design, data analysis consisted of quantitative and qualitative components. With the quantitative component, a series of dependent groups *t*-tests were conducted to explore differences between the pretest and post-test. Student performance related to selected demographic variables was also examined. Qualitative data analysis consisted of examining the transcripts of post-instruction focus groups, which were conducted by the research team to explore students' understanding of core concepts and the efficacy of the study's unit of instruction.

Quantitative Data Analysis

A series of dependent groups *t*-tests were conducted to compare pretest and post-test scores. The initial analysis, which was conducted on the composite test scores, was followed by separate analyses of the instrument's three dimensions (i.e., constraints, optimization, and predictive analysis). Student scores consisted of the number of items answered correctly of the instrument's 30 questions. A significant composite score gain of 3.22 was obtained between the pretest and post-test (see Table 2).

Table 2
Dependent groups t-test for composite test score (n = 114)

	Mean	Std. Dev.	*t*	*p*
Pre-Test Score	14.74	4.872	8.604	.000
Post-Test Score	17.96	4.984		

Total items on the test = 30

While the gain scores were statistically significant, the overall percentage of items answered correctly was somewhat disappointing. Based on focus group discussion and interaction with participating teachers, low composite test scores were attributable to several factors. Among these factors were perceived test difficulty and voluntary participation in the study, where students were informed that test results would not be counted in their semester grades. In spite of relatively low test scores, focus group discussion, however, indicated that students clearly were able to identify the core engineering concepts selected for the study. In the aggregate, they also possessed a relatively sophisticated understanding of the interrelationship among the concepts. Focus group results suggest that the instruction may have been more effective than what the test scores indicate.

In a focus group conducted with participating teachers, there was broad consensus that the test results were negatively impacted by the structure of the test. This included its high readability and conceptual levels as well as difficulties with knowledge transfer between examples used in the instrument and activities used during instruction. In spite of efforts made to validate the instrument during the planning stages of the study, it was clear that the study's outcomes were influenced by these assessment issues. In spite of these issues, the teachers indicated that their students' understanding of COPA concepts was clearly achieved as a result of the study.

Separate dependent groups *t*-tests were also performed on the instrument's sub-scores (i.e., items assessing the three core engineering concepts). Mean score gains ranging from approximately 1 – 1 ½ items were obtained, with the highest gain score on the predictive analysis dimension. All three gain scores were statistically significant (see Table 3).

Table 3
Dependent groups t-test for core concept dimensions (n = 114)

	Mean	**Std. Dev.**	***t***	***p***
Constraints (10 items)				
Pre-Test	6.13	2.106	4.687	.000
Post-Test	6.98	2.018		
Optimization (10 items)				
Pre-Test Score	4.22	1.718	5.513	.000
Post-Test Score	5.12	1.942		
Predictive Analysis (10 items)				
Pre-Test Score	4.39	2.151	7.478	.000
Post-Test Score	5.85	2.019		

n = 114

The instrument's design also included the development of items at three levels of complexity along Bloom's taxonomy of cognitive skills (comprehension, application, and analysis/synthesis). As could be anticipated, the highest net score gain occurred at the comprehension level (2.07) and the lowest score gain was obtained at the analysis/synthesis level (.53) (see Table 4).

Table 4
Dependent groups t-test for conceptual difficulty levels (n = 114)

	Mean	**Std. Dev.**	***t***	***p***
Comprehension (12 items)				
Pre-Test	6.06	2.557	9.277	.000
Post-Test	8.13	2.533		

Application (9 items)				
Pre-Test Score	4.62	1.962	3.613	.000
Post-Test Score	5.25	2.072		
Synthesis (9 items)				
Pre-Test Score	4.05	1.645	2.893	.005
Post-Test Score	4.58	1.499		

As noted above, focus group discussion indicated that the level of students' understanding may exceed that suggested by the test score data. As stated earlier, student scores were relatively low, but subjects' understanding of the three core concepts was evident in the focus groups. For example, a common observation of students was how the three engineering concept dimensions interact with one another in real world engineering design situations. Specifically, students commented on how optimized engineering designs routinely require tradeoffs among constraints (e.g., it is not possible to optimize all constraints; constraints tend to compete with one another).

The data were also analyzed to examine the possible effects of selected demographic factors on student learning. These factors included gender, ethnicity, and level of mathematics and science courses. Analysis of variance procedures, which were conducted on each of the variables, detected no statistically significant differences. Non-significant differences on the selected demographic variables are encouraging. Given the well-documented concern about female and minority involvement in scientific and engineering careers, this study's results indicate that gender and ethnic differences may be minimized or reduced in controlled instructional situations. In other words, gender and ethnically-sensitive instructional design may facilitate learning of engineering concepts in ways that minimize demographic differences. The results of this study are encouraging, given the concern of many technology educators that the growing emphasis on engineering could reduce participation of a broad spectrum of students.

Although not a research hypothesis of this study, the gender composition of the sample is presented in Table 5. The analysis indicated that there were no significant gender differences.

Table 5
Independent groups t-test for gender on post-test concepts
(males = 101, females = 12, = 114 total)

	Mean	**Std. Dev.**	***t***	***p***
Constraints (10 items))				
Pre-Test	6.98	2.044	.032	.974
Post-Test	7.00	1.859		
Optimization (10 items)				
Pre-Test Score	5.15	1.987	.387	.699
Post-Test Score	4.92	1.564		
Predictive Analysis (10 items)				
Pre-Test Score	5.82	2.036	.420	.675
Post-Test Score	6.08	1.929		

Qualitative Data Analysis

All of the focus group students commented on the amount of mathematics and science that was included within the unit of instruction and activities; predictive analysis throughout all of the activities was the least favorite aspect of the twenty-day unit of instruction. With the exception of one focus group, all of the students knew that constraints, optimization, and predictive analysis (COPA) were the key concepts being taught throughout the unit of instruction and provided examples of how and when they learned these concepts. As discussed in the treatment section, each lesson and activity targeted one or more of the key concepts. A majority of the students defined optimization as "the best solution to a problem, balancing trade-offs between competing factors." Students defined predictive analysis as the "mathematical or scientific equations that are used before the artifact or problem is completed." Students defined constraints as "the boundaries for what you can do and the parameters you have to stick to."

Of the three COPA concepts, predictive analysis was the most difficult to understand for the majority of the high school students and constraints was the easiest. A small minority of the students who completed the focus groups identified the COPA concepts as interconnected. Most students used an analogy of the scientific method to COPA. A majority of students were not familiar with optimization and predictive analysis before the treatment, but through their prior or existing technology education courses were familiar with constraints. Almost all students commented that they take technology education courses because they are fun and activity-based, not mathematics or science-based.

All of the focus group students rated the "Volume Barge" activity as their favorite. This activity focused on the concept of optimization. Furthermore, the activity challenged students to compete against their classmates for the best barge. A majority of the focus group students wanted more open design activities that were similar to the barge activity.

Almost all of the focus group sessions revealed that students wanted a launching device, similar to a pneumatic powered device instead of the golf ball launching device that was used in the unit of instruction; students wanted a "boom" effect rather than the gravity fed device provided. Students seemed to like the wall insulation activity because it was more hands-on than the other activities within the unit.

Overwhelmingly, the students in the focus groups commented on how mathematics and science concepts taught throughout the unit were better understood when they were connected to solving a problem or building an artifact. Students commented that they did not understand mathematics and science in their stand alone courses. They also commented on the positive nature of including most of the formulas they would need to solve for problems within student handouts or embedded within the activities. However, students commented that the theory of mathematics and science does not always translate into a properly working artifact.

The last question to each focus group was whether or not this unit of instruction had influenced them to pursue post-secondary studies and a career in engineering or a related field. There was no indication that after completing the twenty-day unit of instruction that a positive or negative influence existed.

Conclusions and Recommendations

Based on the results of this study, some conclusions become apparent. It is clear that student learning was achieved as a result of students' participation in the engineering design unit of instruction. While mean score gains from pre-test to post test were modest, they did indicate significant improvement in understanding of COPA concepts. Given the lack of significant gender, ethnic group, and mathematics/science background performance differences, the study also indicates that engineering concepts can be successfully delivered to a broad spectrum of students. These preliminary results are important since many technology educators are concerned that an engineering curricular focus might appeal only to a more academically capable subset of the technology education student body.

Based on focus group discussions with students and teachers, some important factors emerged related to how engineering concepts were delivered in this study. These factors have important implications for future research, curriculum development, and professional development. One key factor has to do with an overt shift from procedural/activity-based curriculum and instruction, which as been typical for technology education, to an overt concept-based focus. The importance of this shift certainly extends beyond this research study or engineering curriculum. In this era of standards-based instruction, the technology education field must learn how to balance the historical appeal of engaging activities with curriculum development that is specifically designed to teach concepts (standards). While students generally indicated that they enjoyed the study's activities, they also reported that they would have preferred to have actually constructed more of the devices used in the study rather than having them pre-constructed in order to meet the time and treatment fidelity constraints of the study.

Another significant challenge of research of this type has to do with the constraints involved with informed consent research. Focus group results indicate that student motivation to perform well in the study was eroded by their awareness that the test outcomes would not be included in their semester grades.

Another important factor that emerged from the study had to do with the challenges associated with developing high quality, authentic assessments of COPA concepts. The outcomes of the study indicate that the test instrument was capable of detecting student learning at the various levels of conceptual difficulty. The psychometric properties were also sound, with acceptable levels of reliability and validity. Teacher involvement in the development and validation of the instrument used in this study was designed to ensure its appropriateness, including appropriate level of difficulty. However, focus group feedback indicated that students found the items to be demanding both in terms of reading level and conceptual load. While the multiple choice format provided objective data, future research should include more diverse and authentic formats.

Nonetheless, the findings of this study also indicated that there are specific areas of need in order to better develop these engineering concepts. For example, existing and pre-service technology education teachers need to be better equipped to develop and teach instruction focused on engineering design concepts. In particular, professional development focused on preparing technology education teachers to develop and teach instruction that is both concept-driven and activity-oriented is an area of need. Historically, technology education has focused primarily on procedural knowledge through hands-on activities that focus primarily on artifacts. In order to integrate engineering concepts within technology education, technology education teachers need to develop pedagogical skills that include more focus on conceptual knowledge and the processes involved in engineering design, which includes the ability to apply mathematical and scientific knowledge.

Another area of need is the development of sound curriculum, activities, and assessments that target engineering design concepts. The instruction and activities developed for this study appear to have done an adequate job relaying the concepts to the students. However, with more refinement and focus these and similar activities could be used to teach engineering concepts even more effectively beyond the twenty-session research treatment. For example, separate units on constraints, optimization, and predictive analysis may help students better understand these engineering concepts. These activities need to maintain a hands-on component, which is an area of strength for technology education, because it appears to be a key to student motivation. In addition, authentic assessments need to be developed to assess student understanding. As revealed in this study, there are limitations to using tests to assess student learning of engineering concepts, especially at the analysis/synthesis level. Authentic assessments targeted at assessing student's understanding need to be developed to gauge student learning.

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Software Piracy among Technology Education Students: Investigating Property Rights in a Culture of Innovation

George Teston

When asked about individual perceptions of "technology," 68% of Americans primarily equate the term to the computer (International Technology Education Association, 2004). Although this perception under represents the true breadth of the field, the statistic does speak to the ubiquitous role the computer plays across many technology disciplines. Software has become the building block of all major industries and arguably, our modern civilization. Software drives the automation of manufacturing, medical research, avionics, telecommunications, engineering, and even our national defense. With software tools at the heart of design, problem-solving, and innovation for many major technology industries, technology education has accepted the essential role of software.

The International Technology Education Association (ITEA) (2005, p. 25), which supports a broad range of technology disciplines, asserts that students should learn how to apply principles of computer science as early as middle school. Computer science is among the disciplines the ITEA identifies for post-secondary study and technology careers (p.27). Two of the nationally-recognized ITEA Standards for Technological Literacy content standards (eleven and twelve) are supported by the design and problem-solving skills involved in computer programming (ITEA, 2000). In light of this commitment, has the technology education classroom kept pace with the ethical challenges presented by ever-expanding computer contexts?

In recent years, the academic and popular literature has resounded with alarming software piracy statistics (see Al-Rafee & Cronan, 2006; Batson, 2007; IDC, 2007; Kruger, 2004). According to *The Economist* (Gottlieb, 2007) and the *Wall Street Journal* (Batson, 2007), illegal pirated copies of commercial software represented a loss of $39.6 billion in 2006. IDC Research (2007) estimates the loss to mount to $300 billion over the next four years. The Business Software

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Alliance (2006) reports a global piracy rate of 35%, that one in three commercial software installations circumvents purchase. Of the 230 million PC's shipped last year, only seven cents were spent on legitimate software for every dollar spent on hardware. The problem is also recognized by experts beyond industry (Forrester Research, 2005; Pew Internet Foundation, 2007) and by Congress, which formed the 2007 Congressional AntiPiracy Caucus in response to the crisis.

Regardless of the corporate sector's ability to absorb this loss or advocacy groups' cry for free software, piracy robs companies and programmers of their property rights and reduces future jobs for today's technology students. Like engineers, graphic designers, and other members of the technology community, programmers are paid for their creative skills in design and problem-solving. Without revenue for their creative products, the innovation cycle is seriously diminished.

The products of computer programming, and therefore the impact of piracy, touch many other technology fields, including: computer aided design, robotics, informatics, desktop publishing, and artificial intelligence. Yet unlike these fields, the public's interaction with computer software begins at a much, much earlier age. Does this early interaction with software facilitate greater maturity in software property values? Or does the early interaction precede the appropriate developmental window at which property values are formed? As our economic dependence on software continues to grow, the field of education technology must strive to produce future technology professionals who exhibit both facility *and ethics* with software.

This study sought to investigate the attitudes related to software piracy among a sample first encountering the developmental issues of software, students in three middle school technology education programs that include computer programming. The present study also provided comparison to an earlier study (Teston, 2002) to assess changes in piracy attitudes.

Background and Purpose

Because today's young technology education students represent tomorrow's innovators, their ethical development related to intellectual property is of particular concern. Hopper (2000) stated that almost half (48%) of elementary and middle school students believe software piracy is legal. Kruger (2004) reported 40% of adult educators defend piracy within schools. Not surprisingly, student beliefs mirror those modeled by their teachers, with many young people (88%) justifying piracy from a perception that individual software costs only pennies to produce and represents no harm (Kruger, 2004). Since preventive measures and legal deterrents do not seem effective in the face of increasing losses (Al-Rafee, 2006), it is important that we examine the attitudinal variables underlying the piracy phenomenon.

Kohlberg (1989) and Piaget (1965) observed that children acquire property morals through social interaction with tangible objects, whereby they experience loss and empathy. Kohlberg's seminal research in moral judgment provides a framework to predict moral attitudes and behavior. Kohlberg asserts that individuals learn to reconcile ethical decisions according to three progressive levels of moral reasoning: pre-conventional (avoiding punishment), conventional (abiding by law), and post-conventional (principled standards even in the absence of law). Kohlberg's research, which originally focused on fifth through seventh grade students in conflicting moral dilemma discussions, identified adolescence as the critical moral developmental period.

To streamline Kohlberg's methodology, James Rest developed the Defining Issues Test (1986), on which respondents evaluate ethical dilemmas to generate a scaled moral index score. D.I.T. validity and reliability was strongly reaffirmed in 1999 when Rest examined over 400 independently published DIT-based articles (Al-Rafee, 2006).

While taking tangible property creates deprivation and represents a conspicuous act with clear opposing moral norms, pirating software usually does not deprive the owner of property and is far less obvious. Consider the graphic designer pirating photographs, the budding engineer pirating AutoCad, or the robotics student who discovers the ease of simply copying another student's time-intensive programming files. How well, if at all, are these abstractions and ambiguities discussed in the typical technology education class? Technology students may be unprepared to stretch the physical property experiences Kohlberg (1989) described to fit these digital contexts.

While much research, both classical and contemporary, addresses value development from the early adolescent perspective (Kohlberg, 1989; Piaget, 1965; Rest, 1979), little attention has been paid to computer ethics during these formative years. Friedman (1997) studied the motivations for piracy among late adolescents. Teston (2002) and Daniel (2002) extended this research to early adolescents, but no significant body of piracy research exists from the middle school technology education context.

The purpose of this study was to compare the attitudes, reasoning, and behavior in two groups: early adolescent technology students who view software piracy as *ethical*, and early adolescent technology students who view computer-based piracy as *unethical*. These groups were also compared to non-technology middle school students from an earlier study of similar design (Teston, 2002). Students were asked to evaluate statements designed to measure their attitudes toward the ownership of tangible, prototypic property and intangible computer-based property, specifically software. Technology students were also asked about the property rights of other products of technology creativity: blueprints and brochures.

The objectives of this study were to:

1. Determine any difference in value orientation toward traditional, tangible property, and value orientation toward intangible computer-based property among early adolescent technology education students.

2. Determine any difference in the moral reasoning levels of early adolescent technology education students who view software piracy as ethical and those who view software piracy as unethical.
3. Determine if moral orientation toward software piracy is related to actual general ethical behavior among early adolescent technology education students.
4. Determine if adolescent technology education students' perceptions of software ownership are related to their moral orientation toward software piracy.
5. Determine if there is a difference in software piracy attitudes among students in a technology education exploratory class compared to middle school students who have not had a technology education exploratory class.

Methodology

Population and Sample

The population for this study consisted of approximately 640 seventh-grade students from three suburban middle schools. Using technology education class periods as the unit of partition, groups of students were randomly selected, yielding an initial sample of 274. After 23 surveys were disqualified for incomplete or improper responses, the remaining 251 surveys comprised the first phase of analysis, which included a statistical validity check to test for random or meaningless response patterns from the technology students. An analysis of response patterns revealed 14 surveys that were invalid according to the criterion of 50% or greater inconsistency between forced-choice items and counterpart Likert-scaled questions. The statistical analysis, results, and conclusions of this study are based on the remaining 237 valid subjects.

Instrument and Data Collection

A survey instrument was developed and field tested in a pilot study ($n = 47$) that preceded the formal study. The first two sections are based on Rest's (1979) Defining Issues Test, which consists of various dilemma stories to measure values, and has a test-retest reliability range of 70-85%. The D.I.T. has been used extensively in piracy contexts and shown to correlate (r >70s) to Kohlberg's interview methods (Al-Rafee, 2006; Logsdon, et. al., 1994; Wagner, 2001). The next section drew upon the survey content of Friedman (1997), with a prior reliability > 84.6%. The last two sections contained new items on actual property knowledge and behaviors. The test-retest method indicated reliability > 90% between two pilot rounds.

Section A of the survey presents a dilemma in which a girl considers whether to steal a drug for her sick mother. In section B, a boy considers whether to copy a computer game for a friend. Each story is followed by a multiple-choice question that asks how the character should act. Respondents are given a list of 16 justification statements (see Table 1) related to the dilemma and must rate each on a 5-point scale, where 4 indicates greatest importance and 0 indicates none. Sixteen justification statements measure value judgments such as, "Software is too expensive" and "Copying the CD will not harm anyone." Finally, respondents are asked to select the four most important justification issues and rank them. These four issues are then used to produce eight scores that indicate a level of moral development. A series of complex-sounding, yet meaningless items yields two scores that measure consistency, random responses, and subjects "faking good."

Table 1
Students were asked to rate 16 affirmative and negative statements across 8 justification schemes for relative importance to his/her piracy decision.

Justification	Sample statement, +affirmative, -negative
Actor's welfare	Bryan would still have the CD even if he copied it +
Other's welfare	Copying the CD prevents its makers from getting paid -
Other's welfare not affected	Software companies/programmers make money anyway +
Fairness and rights	Software is too expensive +
Social convention	Lots of people copy software to keep from paying for it +
Authority	If there is a law against it, he should not copy it -
Individual issue	Copying software just isn't an important issue -
Meaningless	Bryan uses a Blu-Ray Drive to copy disks.

Sections C and D consist of 14 dichotomous evaluation items. Section C is framed by moral orientation and asks respondents whether it is "OK" to perform various acts relating to tangible and intangible property, such as copying a CD for a friend and copying a protected photograph for a brochure assignment. Section D tests respondents' knowledge of copyright and property-ownership issues. Section E, asks respondents whether they have engaged in various acts of tangible and intangible nature including game pirating, multiple loading, and shoplifting.

Analysis

The first research questions were analyzed using descriptive statistics. The items for traditional property and software (steal, don't steal, indifferent) were analyzed using Chi-square analysis. Descriptive statistics and an independent *t*-test were used to analyze sample mean deviation between the groups for the thirty-two Likert justification scales. Forced choice items were analyzed using frequency distributions and cumulative frequencies. Weighted frequency scores were calculated by using degree of importance (0 to 4) as a multiplier. Finally, these scores were standardized by the number of subjects in each group. Data for the propiracy and antipiracy groups related to specific piracy contexts (self, other, and profit) were placed into bivariate tables and analyzed using McNemar's Test. To assess possible relationships between moral orientation and actual behavior, the Pearson product correlation test was used. The variable of perceived ownership was analyzed using basic descriptive statistics.

Findings

Value comparisons for traditional property and computer-based property

The dilemma evaluations allowed for comparison of traditional, prototypic property orientation and computer-based property orientation. Subjects who indicated indifference were not analyzed (*n* = 57, 24%). For the initial dilemma regarding the drug, 32.0% of subjects supported stealing it, while 43.8% did not. When posed with the dilemma of the software, 52.3% of subjects supported copying the CD, compared to 32.0% who did not. Moral orientation to traditional property was also measured by subjects' evaluation of a bike theft dilemma. Overall, 9.7% approved of stealing the bike. By contrast, 52.3% approved of pirating for self and 63.4% endorsed pirating software from the Internet. When bike theft orientation was compared to software piracy orientation, the difference between groups was significant ($X^2 = 116.42$, P-value=.0000) in favor of piracy. These differences indicate greater moral adherence among middle school technology education students to notions of ownership regarding physical property than to software. This finding corresponds to earlier research (Al-Rafee & Cronan, 2006; Daniel, 2002; Friedman, 1997; Teston, 2002) in which similar differences of moral orientation were found among late adolescents and adults.

Moral reasoning levels across pro-piracy and anti-piracy groups

Based on responses to sections A and B of the survey, subjects were classified into propiracy or antipiracy groups. Sixteen Likert-scale items followed each dilemma to assess respondents' justifications. An independent t test was used to assess sample mean deviation between the groups for the 32 Likert scales of the eight justification categories. Respondents also answered forced choice items rating the significance of their justifications, where 4 indicated greatest importance. Results were compiled by justification categories and standardized by the number of subjects in each group: antipiracy (*n* = 76) and propiracy (*n* = 124).

Results indicated logical consistency between the drug and software contexts for both groups. Independent t tests for sample mean deviation of the Likert justification scores between groups revealed no significant differences ($p < .05$) for the moral justification items related to traditional property. However, the moral reasoning of propiracy and antipiracy groups was quite different regarding software. Independent *t*-tests performed on the Likert scores indicated four significant justification categories for Propiracy students and three for Antipiracy Students.

In addition to the Likert justification items, analysis was performed on the forced-choice questions to measure respondents' reasoning. Frequency distributions for all items were calculated based on each respondent's rating of four items he or she deemed most important in evaluating the dilemma. Weighted scores were created using a factor of 4 for most important, down to zero for no importance. To allow for comparisons across variables, scores were combined into justification categories and then standardized. For the drug dilemma, both propiracy and antipiracy subjects exhibited similar reasoning (greatest to least): actor's welfare, other's welfare, authority, fairness and rights, social convention, and individual issue.

Table 2
Significantly rated justifications (where Likert value 4 indicates greatest)

Propiracy Students	Mean	Antipiracy Students	Mean
Social Convention "everyone does it"	2.98	Authority "law against it"	3.61
Individual Issue "not important"	2.90	Fairness and rights "no right to copy"	3.29
Actor's welfare "self-interest to pirate"	2.71	Other's Welfare "deprives compensation"	2.94
Other's welfare not affected "no one harmed in piracy"	2.69		

Table 3
Forced-Choice Piracy Justification Scores Standardized Across Groups

	Propiracy (n = 124)		**Antipiracy** (n = 76)	
Moral justification	**Traditional Property**	**Software**	**Traditional Property**	**Software**
Actor's welfare	3.17	1.20	3.01	1.78
Other's welfare	1.69	1.47	1.90	1.52
Authority	1.37	1.45	1.40	2.79
Fairness & rights	1.14	1.55	1.42	1.90
Other's welfare not affected	1.04	1.29	1.19	0.17
Social convention	0.92	0.96	0.78	0.73
Individual issue	0.50	1.84	0.30	0.97
Meaningless	0.17	0.24	0.01	0.14

Note: Weighted scores obtained from two survey items each, then standardized across groups.

The forced-choice analysis revealed reasoning differences between groups regarding software. First, both groups demonstrated dominant "actor's welfare" reasoning for traditional property and a dramatic decline of the same reasoning for the software piracy. Second, the antipiracy group exhibited a 99.2% increase in "authority" reasoning preference for the software scenario, almost twice that of the traditional property scenario. Third, both groups showed significantly higher scores in the software scenario for the "individual issue" category. This indicates a higher preference among propiracy students for social convention in software piracy contexts. Lastly, and perhaps most interesting, the "other's welfare not affected" justification was markedly different between groups for the software context, clearly indicating a lack of empathy among the propiracy students for the programmers and companies. This lack of apparent empathy is notable given that these students have all received computer programming experiences in their technology education courses.

Moral orientation toward software piracy and actual general ethical behavior

Eleven yes/no items measured students' general and piracy-related behaviors. With regard to the entire sample, 27.4% reported having shoplifted, while 72.6% denied such acts. The variable for self-reported shoplifting was not significant across propiracy and antipiracy groups. While only 9.7% advocated taking the bike, 69.2% supported copying unauthorized photographs for a brochure design and 58.6% supported copying a former student's CAD files. In terms of actual behaviors, 61.6% of technology students responded that they had actually used another person's CDs for installation of software on their computer and 68.3% indicated that they had copied software CDs for someone else. Of those subjects, 89.3% indicated an otherwise moral orientation by responding that they did not approve of taking the bike. While 52.3% of the sample advocated piracy for the person in the survey scenario, far more (68.3%) reported self piracy behaviors − indicating that 16% pirate even though they do not advocate the act.

Perceptions of software ownership and attitudes toward software piracy

Of the propiracy students, 54.0% indicated that software is public property, compared to 53.9% of the antipiracy students. Pearson correlation analysis results ($r = .0043$) indicated no linear relationship between perceived software property rights and piracy attitudes. Remarkably, over half of students, regardless of piracy orientation, believe that software is public property.

Another item measured ambiguity of software ownership. Without distinction of piracy orientation, 60.3% of respondents indicated that the manufacturer does not retain any property rights to software following consumer purchase. The largest relative response group was clearly the propiracy students who rejected the manufacturer's retention of property rights. Pearson correlation results ($r = -.19$, $p = .0092$) confirmed a modest inverse correlation between piracy orientation and supportive attitudes about authors' retention of property rights. This appears to highlight an instructional need regarding intellectual property rights.

The technology education variable in software piracy attitudes

The final objective of this investigation was to determine if middle school technology education students who have had computer programming exploration would have different attitudes from those measured by Teston (2002) among a general middle school population. The researcher hypothesized that the exposure to programming and design of software solutions in the technology education curriculum would make a positive difference by providing students (a) empathy to the programmer's creative efforts, (b) experience with intellectual property, (c) cursory knowledge of copyright/patent law, and (d) better understanding of the economic impact. Surprisingly, the attitudes of the technology education exploratory group were not significantly different from those measured originally in a general middle school population. In fact, the results were quite congruent. Teston's 2002 study found 51.9% in favor of piracy acts and the present study found 52.3% in favor. Rather than finding more sophisticated moral reasoning related to software property rights, the group appears comparable to their non-technology peers. Yet the technology education students report significantly higher rates of actual piracy behaviors. General middle schoolers reported 45.8% for copied software CDs and 53.4% for pirated installations (Teston, 2002). In contrast, the technology education middle school students reported 68.3% for copied software and 61.6% for pirated installations, 22.5 and 8.2 increases respectively. Perhaps technology education students are simply higher consumers of software given their interests and exposure. Further research in this area would be valuable, as neither the 2002 study nor the present one sought to measure levels of software usage as a possible piracy variable.

Implications for Technology Education

Two of the ITEA STL Content Standards relate to the unique property rights issues highlighted by software piracy: the social and economic impact of technology (Standard 4) and the role of society in the development of technology (Standard 6). Some states have specifically articulated software property rights objectives in their implementation of the ITEA STL Standards (Alabama Learning Exchange, 2007). Additionally, seven mid-western states have addressed software property rights as part of the Mid-continent Research for Education and Learning Standards (2007), which states in Technology Standard 3 that, "Starting in grades 3-5, students will understand the concept of software piracy and that piracy is a violation of copyright laws." Regrettably, many states do not specifically include software property rights in their standards and even fewer appear to address this at the middle school level, a time when Kohlberg (1989) asserts ethics instruction has the greatest impact. This gap highlights significance for the present study and warrants additional efforts by the technology education community.

This study revealed a difference in moral orientation toward traditional, tangible property compared to intangible, computer-based property among early adolescents, but that this difference does not result from different moral reasoning levels between the propiracy and antipiracy students. Instead, the majority of students, 58.7% of the full sample and 62.7% of the propiracy students, had erroneous concepts of innovator's rights beyond the point of sale. This suggests curricular failure to address social convention, misconceptions of software ownership, and copyright laws.

The hallmarks of Kohlberg's (1989) conventional stage are the ability to take another person's perspective and adherence to rules for the sake of social order. Since the stage includes ages nine to twenty, young and late adolescents represent ideal groups to consider Kohlberg's theories in the digital property context. Friedman (1997) found the second most popular justification for pirating software among late adolescents was that it didn't harm anyone, empathetic yet inverted logic. In contrast to Friedman's sample of empathetic eleventh and twelfth graders, this sample of seventh graders presented dominant egocentric (propiracy) and authority-driven (antipiracy) reasoning. This clear difference in empathy supports Kohlberg's and Piaget's (1965) age-progressive reasoning levels. This also suggests that the development of general empathy may not translate to digital property contexts if the individual lacks concrete experience or understanding of intellectual property. Whether due to issues of social convention or perceptions of software that escape prototypic property experiences in childhood, computer software appears to present a unique moral paradigm.

Kohlberg (1989) and Piaget (1965) both asserted that recognition of ownership must precede observance of related property rights. Technology education efforts may therefore offer a positive impact by addressing fundamentals of intellectual property ownership. Not only programmers, but technology education students in all fields of innovation and design (engineering, biotech, information, construction, and manufacturing) should have their growth in skill balanced with growth in ethics.

Piracy behaviors among the present sample of middle school technology students was significantly greater than those reported in Teston's (2002) sample of middle school non-technology education students. In terms of frequency, other research suggests young people engage in piracy more often than older users (Pew, 2007; Wagner, 2001). The significant presence of this behavior at such a young age, coupled with majority misconceptions of property rights, highlights an important outcome for this study. If early adolescence is indeed the optimum period for moral education (Bloom, 1964; Kohlberg, 1989; Piaget, 1965), then piracy education and intervention efforts should be targeted more strategically at this population.

Roger Bybee (2003), a noted advocate for the new standards for technological literacy, asserted that technology involves synthesis of ideas from a variety of disciplines. The interdisciplinary nature of digital property concepts provides ripe opportunity for integration across the curriculum. Teachers can easily leverage the topic of intellectual property rights for connections in math (economics), social studies (copyright laws and cultural differences toward piracy), art (intellectual property types), science (the rights of inventors), and even language arts (plagiarism).

Federal law, which recently increased fines to $250,000 and jail terms to 5 years, stridently reflects the pervasiveness of this problem in our society and the importance of protecting digital innovation (Software and Information Industry Association, 2007). Yet, the current classroom conversation on intellectual property rights appears largely silent. Students rate their teachers dead last for intellectual property instruction (18%, compared to friends 30%, and television 59%), indicating that we are failing to meet this curricular need (Ishizuka, 2004). The technology education classroom, with its culture of design and innovation, is the prime context to address this disturbing gap.

A rich opportunity exists for collegiate technology education leaders to collaborate with grade-school teachers and technology education coordinators to encourage lesson plans and dialogue on intellectual property rights. The 57 university-level technology teacher education programs in the United States also have much to offer this discussion (Warner & Morford, 2004). Their students ultimately become the certified teachers, delivering technology education curricula (both cognitive and affective) in the public school arena.

Technology educators, at all levels, should be exposed to the well-documented instructional methods for ethics education. Kohlberg (1989) provides specific successful strategies for ethics education, the core of which is carefully-led discussions about progressively complex, ethically-conflicting, property dilemmas. These activities in moral conflict and cognitive resolution can help technology education students to dialogue and develop values for a range of technology properties, from engineering designs to software. In support of this, technology education textbooks from middle school to graduate school should include a chapter on ethics – one that appears within the core of the text, not near the end where ethics content is generally relegated.

A number of strategies exist for the technology education community to effectuate positive change in digital property rights:

Pedagogy – integration of property rights issues into design and problem-solving instruction for immediate relevance and interdisciplinary connections

Curriculum – textbooks and resources that specifically address intellectual property rights across the breadth of technology disciplines

Professional Development – strategies to equip technology educators to lead moral dilemma discussions for authentic student change

Research – continued inquiry into digital property attitudes, behaviors, and university connections for pre-service teachers

If we implement strategies to teach technology students to be ethically conscious of innovation and property rights, we will help address the piracy problem facing the software industry today and bolster property rights across all the various fields of technology design and innovation. The rapid rate of technological expansion does not have to exceed our society's rate of moral accommodation.

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Have We Made Progress? Stakeholder Perceptions of Technology Education in Public Secondary Education in the United States

Michael D. Wright, Barton A. Washer, Larae Watkins, and Donald G. Scott

Technology education (TE) professionals have debated the role and purpose of technology education and its predecessors in public education for more than a half century (Akmal, Oaks, & Barker, 2002; Erekson & Shumway, 2006; Sanders, 2001), or perhaps, since its inception. In addition, these professionals have struggled with the "image" and perception that key stakeholders have of the field (Wicklein & Hill, 1996; Benson, 1993; Daugherty & Wicklein, 1993). Many developments have occurred during the past two decades to help clarify these issues such as the name change from the American Industrial Arts Association to the International Technology Education Association (ITEA) (Streichler, 1985), the *Conceptual Framework for the Study of Technology* (Savage & Sterry, 1990), the establishment of the Center for the Advancement of Teaching Technology and Science (CATTS) in 1998 as the professional development arm of the International Technology Education Association (ITEA, 2008), the *Rationale and Structure for the Study of Technology* (1996), the *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000), *Technically Speaking* (Pearson & Young, 2002), and related Standards Addendums (ITEA, 2002)].

The origins of TE have roots traceable to 18th and 19th century influences, specifically the Enlightenment period in European cultures. However, within the United States, these origins are closely tied to economic interests and influences. Industrialists were a powerful influence in moving higher education and, in turn, public education, toward the practical arts. Yet, it was the ideals of John Dewey and their influence on practical application to theoretical studies that pushed this

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practice even further. Thus, Dewey is credited with being the catalyst that triggered much of the growth of technical disciplines in modern American education. By 1913 "the ideal of education for citizenship was virtually inseparable, in practice, from education for practical occupations in the service of industrial needs" (Chafy, 1997, p. 16). This would suggest that much of the origins of TE were tied to the practical needs of industry or job-relevant training.

Differing perspectives regarding of the role and purpose of TE in public education within the United States continue to be widely debated and publicized. Not only has the problem been exacerbated by disagreement and confusion within the TE profession, but also by differing perceptions *outside* the field. In their study of exemplary TE teachers and their associated secondary faculty in math and science, Daugherty and Wicklein (1993) found that math and science teachers *did not* perceive "the study of the development of technology, biological systems, and transportation as being characteristic of technology education" (p. 41). Furthermore, Daugherty and Wicklein found a significant difference between the perceptions held by math and science teachers when compared to exemplary TE teachers. "While there are many examples of successful technology education programs that are grounded in the separate subject approach" (Erekson & Shumway, 2006, p. 27), a great deal of time and effort continues to be committed to reducing the perceived *identity crisis* of the TE profession.

During the past two decades, many leaders in the TE profession, particularly those in the ITEA, have made concerted efforts to align the field with the math and science communities, and most recently, with pre-engineering education. Additionally, how strongly standards-based reform movements are affecting the perception of TE are not clear. Therefore, one of the key questions driving this study was to determine the extent to which these developments have influenced the perceptions of TE stakeholders.

According to Wicklein and Hill (1996), the identity crisis, or perceptions thereof, includes both internal and external ignorance about the field, which is being exacerbated by a resistance to change among TE professionals. Prior to the release of the *STL* (ITEA, 2000), Wicklein and Hill observed:

> Technology education professionals should also give attention to clarification of academic content and identity….As content is clarified within the profession, internal questions of identity will be largely alleviated. Once this has happened, issues of identity with external entities can be adequately dealt with… (p. 8).

The publication of *Standards for technological literacy: Content for the study of technology* (ITEA, 2000) and related addendums have provided a consistent, focused clarification of academic content. Has this contributed to the current misunderstandings of TE as a profession?

According to Akmal et al. (2002), confusion as to the philosophical orientation of TE still exists. One enduring perspective posits that TE is, or should be, more closely aligned with Career and Technical Education (CTE), particularly the Trade and Industrial (T&I) area. Additionally, many believe TE and T&I share a similar content base. This point was made clear in Rogers (1995) survey of secondary T&I instructors' perceptions of the TE curriculum. These instructors indicated a significant preference "for the more traditional competencies, such as identification of common hand tools and knowledge of basic materials and processes over more contemporary competencies, such as knowledge of future technologies, the invention process, and high-tech applications" (p. 71).

Technology education has also been championed as a K-12 *general education* program. Many TE professionals have long advocated the social purposes of TE, and its predecessor, industrial arts as being equal to, or perhaps more important than skill development. In this light, Chafy (1997) issued a challenge to TE professionals to move away from skill development toward general education:

> Technology education must seek to go beyond the transmission of the most effective and economic usage of "tools" in modern society to include critical investigations of the social purpose of technology. This means embracing a critical approach to technological issues, considering so-called humanistic and social science perspectives on the role of technology in society, and empowering all students to engage in a critical dialog around technology, progress, education, and the meaning of civilizational advancement. (p. 17-18)

In contrast, it would appear the social purposes of TE were apparently not considered by the T&I teachers in Rogers' (1995) study.

Design and *engineering* themes have started to emerge as the primary purpose(s) of technology education. Similarities exist in that both themes view technology as designing creative solutions to help humans adapt to their environment. "…As such, technology should be studied and experienced by all as part of general education" (Raizen, Sellwood, Todd, & Vickers, 1995, p. 11). Indeed, fifteen years ago Benson (1993) suggested the TE field organize and align itself with engineering disciplines. More recently, the ITEA adopted a tagline of "*Technology, Innovation, Design, and Engineering*." Additionally, the ITEA-CATTS consortium has made a concerted effort to market *EngineeringByDesign* (ITEA, 2008) as their primary product and focus. Thus, there continues to be an increasing interest in focusing on the engineering aspects of TE (Benson, 1993; Roman, 2006; Wicklein, 2006; Wright, 2004).

The literature reviewed for this study indicates the role, purpose, and goals of technology education are not understood by all, and vary by internal and external groups. Clearly, the purpose of TE as outlined by Chafy (1997) and Raizen et al. (1995) is consistent with the belief that, as a school subject, TE is part of general education, and not CTE. Yet, others assert the current pre-engineering focus of TE places it squarely back in CTE, albeit different than the T&I perspective described above. As evidenced by the conflicting viewpoints presented, there continues to be confusion and a lack of consensus regarding the purpose of TE. Therefore, one must ask if progress has indeed been made in clarifying the role and purpose of TE among key stakeholders.

Purpose

Akmal et al. (2002) and Sanders (2001) acknowledged the 100-year debate on the purpose[s] of technology education and its debatable ties to industrial arts. The debate has been further fueled by the fact most states classify TE as career and technical education. However, some of these states allow Carl D. Perkins federal funding to support TE while others do not. Therefore, the purpose of this research was to determine the perceptions of selected stakeholders with respect to the role and purpose of TE in public secondary education in the United States. Based on this purpose, the following research questions were developed to guide the study:

1. What are the perceptions of various education personnel regarding the purpose of TE in public secondary education?
2. How is TE classified by state departments of education?
3. To what extent are Carl D. Perkins federal funds used to support TE?
4. What are the perceptions of various education personnel regarding whether TE programs and personnel are treated comparably to other school programs and personnel?

Methodology

Population and Sample

The population for this study was technology education stakeholders including classroom teachers, principals, area career center directors, counselors, state department supervisors, state directors of career and technical education, and university technology teacher educators. Consistent with Patten (2004), to provide the best information possible, the purposive sample for this study consisted of those technology education stakeholders who subscribed to selected electronic listservs related to TE (see Table 1). Based on the volatility of electronic subscriptions resulting in individuals adding or removing their names from listservs at any time, a definitive count of the population could not be determined. While Field (2005) asserted a sample is only representative of its population if drawn randomly, true random sampling was not possible for this study. Thus, broad generalizations of the findings of this research should be made within the context of this sample and the resulting data must be interpreted accordingly.

An invitation to participate in the survey and a link to the survey web site was emailed to selected stakeholders of TE through 11 different listservs (see Table 1). In some cases, the survey invitation was emailed directly by the researcher, and in other cases it was emailed by a member of that respective listserv. Four hundred-twenty nine respondents accepted the Human Subjects release form on page one of the survey instrument. The study sample consisted of 381 respondents who answered all of the required demographic fields which allowed them to gain access to the content questions.

Table 1
Organizational listservs to which the invitation to participate was posted

Group/Organization
Council for Technology Teacher Education of the International Technology Education Association
Idea Garden - International Technology Education Association
Mississippi Valley Technology Teacher Education Conference
Missouri Association of Secondary School Principals
Missouri Council of Career and Technical Administrators
Missouri School Counselors Association
National Association of State Directors of Career & Technical Education
Project Lead the Way national teachers network
State Supervisors of TE
Technology Education Association of Missouri
Technology Education Division of the Association for Career and Technical Education

Instrumentation

Due to the relatively large size of the population, an electronic Web-based survey instrument was determined to be the most efficient means of collecting the data. Dillman (2000) suggested Web-based surveys are as effective as traditional paper surveys and can reduce data collection time from weeks to hours. Surveys are also recognized as a primary method of collecting reliable and valid information directly from study participants about their feelings, motivations, and beliefs (Fink & Kosecoff, 2005). In addition, Web-based methods can reduce the cost of conducting large-scale surveys when compared to traditional mailing costs (Dillman, Fink & Kosecoff).

Another factor in designing the instrument was the desire to ask follow-up questions to elicit more specific details when appropriate. Specifically, the researchers wanted to be able to ask additional questions of members of certain groups. A Web-based survey also provided options not available with other types of survey instruments. According to Dillman (2000),

> Being able to ask questions with many answer choices in a closed-ended fashion makes it possible to use the answer as a screening question that directs respondents to a unique set of questions about the state in which they live, something that would most likely be impractical for a paper questionnaire. (p. 354)

Upon consideration of all factors, implementing a web-based survey was determined to be the best instrumentation option for this study.

The researcher-developed survey instrument was organized into five content sections with 23 questions as well as a demographic section. In detail the items were distributed as follows: Demographics (3 required fields, 3 optional fields); Purpose of TE (6 questions); Classification of TE (2 questions); Use of Carl D. Perkins Federal Funds (2 questions); Technology Educators' Actions to

Influence Federal Funding (3 questions); and Treatment of TE in Public Secondary Schools (10 questions). Content validity of the survey questions was established through the participation of a select group of TE stakeholders. This eight-member group included technology education classroom teachers, technology education teacher educators, a state supervisor for technology education, a representative of state career and technical education directors, a state director for counselor education, and an independent researcher not affiliated with this research. This group validated the final version of the survey in that it measured what it was intended to measure.

The opening page of the survey outlined potential participants' rights as human subjects. This page required each participant to make a selection (forced) indicating consent prior to being directed to the first page of survey questions. The first page of the survey requested demographic information that consisted of three required fields: (a) state, (b) membership in professional associations, and (c) current employment position. Respondents were required to answer all three fields before being directed to the content portion of the survey.

Several questions had sub-questions that only appeared if a specified response was given to the primary question. For example, if a respondent indicated "Yes" to a question, they may have received another question or series of questions to provide more detailed information. A respondent who answered "No" to the same question was not presented the sub-questions.

Since the data collected were primarily nominal data, a Chi-square test was determined to be appropriate to determine statistical significance. The findings are presented consistent with the four research questions.

Findings

The findings of this research are based on 381 respondents who answered all of the required fields, thereby gaining access to the content questions. Two hundred six (54%) of the respondents were from Missouri, 175 (46%) were from other states. As discussed below, statistical tests indicated no significant difference in responses when disaggregated by state.

Demographics

The 381 survey completers represented 39 states and one US territory (American Samoa). Eighty percent (80%) of the respondents were male, 19% female, and 1% did not indicate their gender. Many of these respondents held memberships in multiple professional associations. The distribution of professional memberships is presented in Table 2.

Five associations were specific to Missouri. To determine if the number of additional listservs in Missouri might have had a state-specific influence on the overall data, Missouri and non-Missouri responses were compared. Notably, there were no practical or statistically significant differences between Missouri and Non-Missouri respondents except with respect to the magnitude of the response. These data will be discussed in the appropriate setion. The employment *Positions* reported by the respondents are presented in Table 3.

Table 2
Memberships in professional associations (n=409)

Professional Association	*f*	%
Association for Career and Technical Education (ACTE)	127	33.3
Council for Technology Teacher Education (CTTE)	67	17.6
International Technology Education Association (ITEA)	167	43.8
Mississippi Valley Technology Teacher Education Conference (MVTTEC)	23	6.0
Missouri Association of Career and Technical Education (Mo-ACTE)	77	20.2
Missouri Association of Secondary School Principals (MASSP)	79	20.7
Missouri Council of Career and Technical Administrators (MCTTA)	45	11.8
Missouri School Counselors Association (MSCA)	6	1.6
National Association of Secondary School Principals (NASSP)	71	18.6
Project Lead the Way® national teachers network (PLTW)	58	15.2
Technology Education Association of Missouri (TEAM)	54	14.2
None	29	7.6

Note: Multiple responses were allowed

Although initial data analyses were attempted using all 381 respondents, the researchers, in consultation with a statistician, excluded the responses from counselors and state directors of CTE due to insufficient cell size. Therefore, the following findings are based on 363 respondents.

Table 3
Positions held by respondents

Position	*n*	%
Principal	87	22.8
Teacher educator	84	22.0
High school TE teacher	82	21.5
Middle/junior high school TE teacher	48	12.6
Area CTE school Director	44	11.5
State supervisor for TE	18	4.7
State director of CTE	12	3.1
Counselor	6	1.6
Total	381	100.00

Purpose of Technology Education

Research Question One was addressed by six items regarding the respondents' perceptions of the purpose of TE and pre-engineering programs. The first three items requested the respondents to categorize the purposes of TE in public schools into one of three groups: ***Historical*** (what existed in the past),

In Theory (conceptually what should be), and ***In Practice*** (what currently exists). The fourth question allowed only a single response to indicate what the respondent believed to be the ***Primary Purpose*** of TE. The last two questions of this section focused on the purpose of pre-engineering programs (e.g., Project Lead the Way® [PLTW]).

Table 4
Purpose(s) of technology education (n=363)

	Historical		***In Theory***		***In Practice***	
Type of Program	***f***	**%**	***F***	**%**	***f***	**%**
Academic program/course of study	77	21.2	135	37.2	113	31.1
Avocational program/course of study	113	31.1	64	17.6	103	28.4
CTE program/course of study	203	55.9	230	63.4	219	60.3
Pre-vocational program/course of study	154	42.4	133	36.6	159	43.8
Pre-engineering program/course of study	33	9.1	113	31.1	104	28.7
Don't Know	17	4.70	10	2.8	11	3.0

Note: Multiple responses were allowed

The dominant response for the ***Historical***, ***In Theory,*** and ***In Practice*** purposes of TE was "Career & Technical Education." For ***Historical*** and ***In Practice***, "Pre-vocational" was the second most frequent response. Table 4 presents a comparison of the responses.

However, when forced to select a single ***Primary*** purpose of TE, "Career & Technical Education" was selected more than twice as often as the next highest response of "Academic program." A Chi square test indicated statistical significance (p = .000) (see Table 5). This response was consistent among respondents' *Position* groups as listed in Table 3. There were no statistically significant differences by position with regard to CTE as the primary purpose of TE. However, there was practical significance in that *all* groups indicated CTE was the primary purpose of TE.

The researchers further analyzed the data by subdividing the respondents into two groups based on membership in either ACTE or ITEA, but not both. While both groups agreed CTE was the primary purpose of TE (ACTE = 65.3%, ITEA = 40.8%), there was a statistically significant difference in the magnitude between the membership groups (p = .000).

Table 5
Primary purpose of technology education (n = 325)

Type of Program	***f***	**%**
Academic program/course of study	62	19.1
Avocational (hobby or recreational) program/course of study	19	5.8
Career and Technical Education program/course of study	*157	48.3
Pre-vocational program/course of study	52	16.0
Pre-engineering program/course of study	18	5.5
Don't Know	17	5.2
Total	325	100.0

* $p = .000$

Since responses from listservs in Missouri exceeded those outside of the State, Missouri and non-Missouri responses were compared. For Question #4, the ***primary*** purpose of TE, the results were virtually identical. Among non-Missouri residents, 48.4% indicated that CTE was the primary purpose of TE compared to 48.3% of Missouri respondents. There were no statistically significant differences between Missouri teachers and all other respondents (p = .058).

Pre-engineering perceptions.

The perceptions stakeholders held with respect to pre-engineering courses and programs (e.g., PLTW®) was also investigated in light of the current trend to focus on engineering as a main component of TE. Thirty-five percent (35%) of the respondents indicated the primary purpose of pre-engineering programs was "Career & Technical Education" (see Table 6). Twenty-six percent (26%) of the respondents indicated "Academic" was the primary purpose of pre-engineering programs, contrasted with 19% who indicated "Academic" for technology education programs. There were no statistical differences between respondent groups by position (e.g., teacher, principal, teacher educator, etc.).

Table 6
Primary purpose of pre-engineering programs (n = 321)

Type of Program	***f***	**%**
Academic program/course of study	84	26.2
Avocational (hobby or recreational) program/course of study	5	1.6
Career and Technical Education program/course of study	112	34.9
Pre-vocational program/course of study	33	10.3
Don't Know	87	27.1
Total	321	100.0

Classification of Technology Education in State Departments of Education

The perception of 55% of the respondents was that TE as a subject is classified as CTE in their state. Seventeen percent (17%) indicated TE was classified as Academic, with 17% indicating they didn't know (see Table 7).

Table 7
Classification of technology education by departments of education (n = 332)

Classification	*f*	%
Academic	57	17.2
Avocational	5	1.5
CTE	184	55.4
Pre-vocational	23	6.9
Pre-engineering	6	1.8
Don't know	57	17.2
Total	332	100.0%

Two-thirds of the respondents indicated that TE is administered in CTE units within their State Departments of Education (see Table 8).

Table 8
Administrative location of technology education in doe (n = 332)

Administrative Unit	*f*	%
Curriculum & Instruction	53	16.0
Career & Technical Education	223	67.2
Don't know	45	13.6
Other	11	3.3
Total	332	100.0

Use of Carl D. Perkins Federal Funds

Seventy percent (70%) of the respondents, representing 31 states, indicated it was permissible to use Carl D. Perkins federal funds to support TE programs in their state. Of the respondents reporting they were permitted to use Perkins funds, 83% reported they actually received these funds, representing 29 states. The items for which they are allowed to use federal funds are listed in Table 9. The majority of the respondents (76%) felt that Carl D. Perkins federal funds were *critical* to maintaining TE as a subject in secondary schools in their state.

Technology educators' actions to influence Carl D. Perkins federal funding.

One hundred eighty-six respondents wrote 208 comments related to what actions technology educators are taking to influence Carl D. Perkins funding for TE. The comments were grouped into seven categories by the researchers. Three individual raters independently reviewed the comments to categorize them. Consensus was reached on 100% of the comments. Even though 76% of the respondents indicated Perkins funding was critical to maintaining TE programs

Table 9
Uses of Carl D. Perkins federal funds

Use of Perkins Funds	*f*	%
Equipment	79	27.3
Professional Development	67	23.2
Curriculum Development	62	21.4
General Operations	36	12.5
Salaries	30	10.4
Special Incentives	7	2.4
Other	8	2.8
Total	289	100.0

in their state, when queried about what specific actions technology educators were taking in their state to influence Perkins legislation, 43% indicated either *nothing* or they were *not aware of any actions* Lobbying legislators was the next most frequent action being taken, cited by 28%.The specific actions taken by technology educators to influence Carl D. Perkins federal funding to include TE as reported by survey respondents are listed in Table 10.

Table 10
Actions by technology educators to influence Perkins funding

Actions Being Taken	*f*	%
Nothing – No Actions being taken	24	11.5
I don't know of any actions being taken	65	31.3
Lobbying legislatures/writing/calling	59	28.4
Relying on associations to lobby	19	9.1
Revising programs to become "fundable" under Perkins	19	9.1
Relying on Superiors or State Dept. to lobby	12	5.8
Other	10	4.8
Total	208	100.0

Treatment of TE Programs and Personnel in Public Secondary Schools

The treatment of TE as a subject, as well as technology educators, in public secondary schools is a complex issue and highly subjective. Nevertheless, the perception may be as important as reality. It describes the human and physical environment in which TE professionals work on a daily basis. This section of the survey asked respondents to indicate whether they believed TE as a subject and its teachers were treated comparably to *core academic teachers/subjects* and other *career & technical education teachers/subjects*. For those who indicated they believed TE was treated differently, a subset of questions allowed them to indicate how it was treated differently (*more* or *less* on several key factors).

The respondents were evenly divided on the question of whether TE teachers are treated comparably to core academic teachers, with 51% responding *Yes* and 49% *No*. However, there was a statistically significant difference (p =

.000) in the response of principals compared to all other groups; principals indicated more frequently that they perceived TE teachers were treated comparably to core academic teachers. Overall, *less respect/status* was perceived to be the primary way in which TE teachers were treated differently than core academic teachers, followed by *class time being valued less by administrators* (see Table 11).

Eighty-three percent (83%) of the respondents believed TE teachers were treated comparably to CTE teachers. Once again, there was a statistically significant difference (p = .022) in the response of principals compared to all other groups, with principals indicating more often that they thought TE was treated comparably. The results were the same as for core academic teachers, with respondents indicating TE teachers received *less respect/status* as the primary factor in which TE teachers were treated differently, followed by *class time being valued less by administrators*. Table 11 lists how respondents who indicated a difference believe TE teachers are treated differently than core academic and CTE teachers.

Table 11
Perceptions of equity of TE teachers' treatment compared to academic and CTE teachers

	Academic		CTE	
Topic	**More %**	**Less %**	**More %**	**Less %**
Inclusion in faculty activities	12	55	4	17
Respect/status/ perception of value as a professional	6	112	3	31
Funding for professional development	12	64	4	20
Assignment of extra duties during the school day	27	25	9	8
Class time valued by administrators	4	91	3	24
Protection of planning time	8	48	3	14
Other	5	10	0	6

Sixty-seven percent (67%) of the respondents felt that TE as a subject was *not* treated comparably to core academic subjects. There was a statistically significant difference in the response of principals compared to high school teachers (p = .000). Seventy-nine percent (79%) of the principals indicated TE as a subject was treated comparably to academic subjects, compared to only 16% of the high school teachers. There was strong agreement that a lack of *respect/status/program value* was the primary way that TE was treated differently than core academic subjects, selected more than twice as often as any other factor by those who indicated TE was not treated comparably.

In contrast, 79% of the respondents indicated they believed TE as a subject was treated comparably to other CTE programs. Again, there was a statistically significant difference in the response of principals compared to high school teachers (p = .030). While only 79% of the high school teachers indicated TE as a subject was treated comparably to other CTE subjects, 94% of the principals indicated it was treated equally.

The survey respondents indicated strongly that they believed TE *was* used as a dumping ground in public secondary education (65.7%), and even stronger that pre-engineering programs (e.g., Project Lead The Way®) were *not* a dumping ground (87.6%). There was a statistically significant difference (p = .000) between principals and the other groups, with principals stating that TE was not a dumping ground. There was also a statistically significant difference between middle and high school TE teachers' responses (p = .047), with high school teachers more frequently envisioning TE as a dumping ground. However, there were no significant differences between middle and high school teachers' responses that pre-engineering courses were not a dumping ground (p = .829)

Nearly as many respondents indicated that TE was *not* a college prep curriculum (82.5%) as indicated that pre-engineering programs *were* (76.9%). Expressed differently, more than four times as many respondents indicated that pre-engineering programs (e.g., PLTW®) were college preparatory compared to TE programs. Students enrolled in TE were *not* believed to be primarily college bound, contrasted with pre-engineering programs. There was not a statistically significant difference among groups in this perception.

Summary and Conclusions

Although respondent demographics may limit the generalizability of the data, the 381 respondents from 39 states and one U.S. Territory represented an interesting perspective on the field of technology education. The self-report data supported the assertion that TE leadership has struggled for decades to define TE as a "new basic," a core academic subject in the public schools comparable to math and science. To this end, leaders have lobbied to position TE as a general education subject apart from CTE. However; as revealed by the survey response data, lobbying efforts have failed to convince the professionals within the field who participated in this study.

Historically, in theory and in practice, the survey respondents perceived TE to be a CTE program regardless of their employment position. The respondents selected CTE as the "primary" purpose of TE more than twice as often as they indicated it to having primarily an academic purpose. Nearly half of the respondents who indicated this also identified themselves as members of ITEA only, and not members of ACTE. This constitutes an apparent contradiction with the stated goals and activities of the ITEA leadership. Pre-engineering programs were also viewed as CTE, but not to the same magnitude as technology education. This finding is interesting in that the dominant pre-engineering program (PLTW®) has worked closely with the CTE field and leadership, even embracing CTE as a viable partner and avenue for its delivery. If pre-engineering is a major component of TE, why do these apparent discrepancies exist?

To illustrate these discrepancies, a majority of the respondents classified TE as CTE in their respective states. This status remains despite more than two decades of intense work to position TE as a general education subject. The data from 29 states also suggested that it was permissible to use Perkins funds for TE programs and identified these funds as critical to maintaining TE programs. Ironically, 43% were unaware of any proactive actions being taken to ensure TE's continued eligibility in the Perkins program. This came as a surprise in that ITEA leadership has actively sought to distance TE from CTE.

Respondents were evenly divided on whether TE teachers were treated comparably to core academic teachers. However, there was a significant difference in the perception of principals, who believed the two groups of teachers were treated comparably. While the respondents indicated TE *as a subject* was not regarded comparably to core academic subjects, the principals again differed from the rest by indicating that they felt TE was regarded comparably to core academic subjects.

Is there truly a difference in the treatment of TE and principals failed to acknowledge or realize it? While it is possible that principals provided responses that might be "politically correct," one may assume survey results are based on the assumption that respondents, when guaranteed anonymity, will provide honest and truthful responses. Concomitantly, one could argue that the TE profession is carrying "baggage" – that we may have a lower opinion of ourselves and our self-worth than do others.

TE was also viewed as a dumping ground, a stigma that has long prevailed in CTE. While high school TE teachers supported this view, there was a significant difference in perceptions indicated by middle school TE teachers. Given the nature of the differences between middle and high school programs, this finding was not surprising. Conversely, pre-engineering programs were *not* perceived as a dumping ground.

The data also suggested that TE was *not* a college preparatory program and TE students are not, for the most part, college bound. However, pre-engineering programs like PLTW® were viewed as college preparatory programs four times as often as TE programs. These views were consistent among the groups represented, including TE professionals. If TE professionals believe that their students are not college bound and its curriculum is not college preparatory, how can it attempt to change societal perceptions that they perceive to be negative?

Based on these data, one may conclude that TE sees itself as a CTE program and not a college preparatory subject. Each of the various employment positions represented in this study shared this perspective. While advances within TE have attempted to move the profession toward becoming a core academic subject partnered with math and science, TE continues to be perceived as career and technical education by its own members and other stakeholders. Despite decades of work on the part of the ITEA leadership and others to fund TE programs separately from CTE programs, the respondents to this survey maintained TE is a CTE program and Perkins funding is critical to its survival. Unfortunately, funding allocations often determine what happens to TE programs. Programs can suffer significantly when resources are limited and the competition for them increases (Akmal et al., 2002).

There are clearly different perspectives about pre-engineering programs in contrast to TE programs. If pre-engineering is such an important part of TE, as some profess, then why does this apparent discrepancy exist? It is unclear why pre-engineering programs, such as EngineeringbyDesign and PLTW® that grew to a large extent out of TE, are not viewed the same as technology education. Have we made progress in positioning TE as "The New Basic?" If engineering programs such as EngineeringbyDesign and PLTW® are excluded, then the researchers conclude that the respondents believed the answer is "no."

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