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Articles

Bits and Pieces

The 21st Century of Technology Education

As we move into the future we need to step back and see where the world is going. Business and industry are making major changes and the expansion of technology is changing the way we think and how we do things. Even the way we learn is different today; students are not the same as they were 20 years ago. With all the changes in the world it would only make sense that we should look at the way we teach and make changes needed to be successful in the future. Technology education is no exception to all the change happening today. We must meet the future needs of our students and provide them with the skills needed to be successful in the ever changing world. We must be proactive and move into the 21st century of technology education.

Many educators do see this need and are beginning to make changes now. When you read the research presented in this Volume 48-1 of JSTE, you will see the great work that is being done to move technology into the 21st century.

In This Issue

We start off Volume 48-1 with two *At Issue* articles. The first is written by Marin Petkov and George Rogers, titled *Using Gaming to Motivate today's Technology Students.* In this article the authors state that technology is becoming a big part of American life and today's students are geared toward this new way of learning. Education in American schools needs to change with the times and adapt to this new way of learning, giving up the more traditional lectures and going with what helps today's students learn best. The authors talk about using gaming as a method that motivates students and increases their learning. Gaming is a great tool to increase students learning and today's video games are being designed to do just that.

The second *At Issue* article, *The Gary Plan: A Model for Today's Education,* written by Kevin J. Kaluf and George Rogers, deals with education reform. Many technology education programs are being reduced or eliminated due to budget cuts. With these cuts the question becomes, who will teach students the skills necessary to be productive citizens and keep this country at the top industrially and economically? Many people have attempted to answer this question over the years. One plan identified by the authors does a detailed job of presenting answers to the problem. The Gary Plan of "work-study-play" developed by William Wirt presents an innovative way to implement and encourage hands on activities that provide problem solving and career-related skills. The authors then go on to tell how the plan evolved and many of the problems that had to be overcome before it was successful.

After these first two *At Issue* articles about improving technical education and providing skilled workers, we have a manuscript written by Thomas Wilkin and Godfrey Nwoke dealing with recruiting career and technical education (CTE) teachers to help overcome the shortage of skilled workers in this country. To do this, the authors conducted a three part study, CTE trends in education; status of CTE education in the New York City Public Schools and the highly successful program "Success Via Apprenticeship (SVA) program; and to establish recommendations for the future. Successful SVA programs can and do have a major impact on CTE education recruiting, and retaining qualified teachers is the first step. The authors also suggested a cooperative effort between industry and education to address the cost of CTE programs. In the end, a concentrated effort from state to state must be conducted to find future CTE students. In an effort to find students to fill technical education classes we need to insure that we match the right student to the right program. The next manuscript in this volume deals with this question while placing students in an engineering program. Raymond Dixon wrote about this in his manuscript titled *Selected Core Thinking Skills and Cognitive Strategy of an Expert and Novice Engineer.* The author addresses topics ranging from how students learn engineering and design concepts to the most effective methods of preparing pre-service teachers. The main purpose of the study was to analyze and explore the thinking skills of a student as compared to those of an expert engineer and to see how these skills influence their overall cognitive strategy as they solve a common engineering design problem.

Nolan Fahrer, Jeremy Ernst, Theodore Branoff and Aaron Clark conducted their research to investigate the differences between performance and cognitive assessment scores in a 3-D modeling unit of an engineering drafting course curriculum. Their manuscript titled *Performance and Cognitive Assessment in 3-D Modeling* consisted of testing 92 high school students enrolled in Drafting II-Engineering classes. Although the results of their study showed that there was no significant difference between performance and cognitive assessment, the authors did feel that it was necessary to develop and implement more performance-based assessments in Career & Technical Education that require students to exhibit both skills and knowledge.

The STEM Initiative: Constraints and Challenges, authored by Dennis Herschbach talks about the implications of STEM programming that will aid the engineering, vocational, technical, and technology education classes. In this manuscript the author talks about the considerable national interest in

STEM initiatives and how it represents a way to think about curriculum changes. While the STEM initiative requires an integrated curriculum design, it moves away from the more traditional method of teaching by separate subjects. The application of each pattern is examined in reference to how knowledge is taught and used. The author ends his manuscript by providing insight on how shifting from the traditional methods of teaching separate subjects to the STEM initiative will expose students not only to the way that formal knowledge is learned but also to ways that it is applied.

We finish off Volume 48-1 with an Under Review article by David Bjorkquist. David wrote a review of a book titled *There is Power in a Union: The Epic Story of Labor in America by* Phillip Dray. This is an excellent book detailing the history and development of labor unions in the United States. It begins with the first textile mills in Lowell, Massachusetts through our present day and further. The book identifies individuals and events that shaped labor in this country.

As can be seen by reading these outstanding articles and manuscripts in volume 48-1 of JSTEM we are moving technology education into the 21st century and beyond, and it should be an exciting time.

Using Gaming to Motivate Today's Technology-Dependent Students

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Abstract

In the past several decades, technology has become a big part of American society. It has changed the way people interact with one another as well as how they proceed with everyday life. However, K-12 educational systems have been resistive to change, with most American schools still using traditional instruction in the classroom, consisting mainly of lectures and textbook readings. Lectures are focused on the teacher with minimal student interaction in the discussions. Research has shown that outdated traditional instruction does poorly in motivating the students. However, motivation is a very important factor in academic success. This paper will talk about the use of games in the classroom to increase the students' motivation.

Introduction

Technology such as cell phones, computers, and the Internet, which once were considered luxuries, are now an essential part of society (Adada & Styron, 2008). According to

Escobar-Chaves and Anderson (2008), American youth spend an average of six to eight hours a day using these types of technologies. Technology has changed the way people interact with one another as well as how they proceed with everyday life. The world is changing to accommodate the new way of life but K-12 educational systems have been very resistive to change and still use traditional instructional methods in the classroom (Pannese & Carlesi, 2007).

As noted by Heck, Poindexter, and Garcia (2000) traditional instructional methods consisted of teachers providing lectures and students completing textbook readings. The authors go on to explain that these lectures are heavily focused on the teacher and there is minimal student interaction in the discussions. Prensky (2004) noted that traditional instruction methods lack the motivational incentives needed to keep today's students engaged in the instructional content. Today's world and today's students are vastly different than the way they were a few decades ago. Educational methods that have worked on past generations of students are not as effective for today's technology-dependent generation (Pannese & Carlesi, 2007).

If the way students interact with the world has changed, why is the educational system not changing? K-12 educational systems need to incorporate the use of technology to accommodate the technology-dependent students of today. The use of video games in the classroom may be a method to motivate today's students. These types of games are known as "serious games" whose primary goal is not entertainment, but instead to educate the user (Michael & Chen, 2005).

Video Games as Motivation Tools in the Classroom

Linnenbrink and Pintrich (2002) indicated that motivation is the enabler for learning and academic success.

Learning that takes place is attributed to how well the students are motivated. Based on this theory, if students are motivated they will be successful in school. So what is motivation and how does it work? As defined by Wlodkowski (1999), motivation explains the behavior which is targeted towards a specific goal. It is the driving force behind and explains someone's actions. According to Grolnick and Ryan (1990) the classroom climate and teacher interaction is one of the most crucial roles in how well students are motivated. Students need to be motivated for the students to want to learn in school.

How can a teacher motivate technology-dependent students in a classroom? How can the teachers make the material relate so that the students will want to learn? All of these questions do not have one right or wrong answer. However, the fact is that traditional instructional methods are not motivating today's technology-dependent students (Prensky, 2004). Banathy (1994) indicated that traditional instructional methods are a major reason why the educational systems are obsolete. According to Annetta, Murray, Gull-Laird, Bohr, and Park (2006) K-12 schools are lacking the instructional technology in their curricula which students have grown accustomed to using in everyday life. Educators need to embrace and use technology in the classroom.

So what type of technology is needed in the classroom instruction to increase the students' motivation? To be able to answer this question, it is important to look at what technology-dependent students like to do when they are not in school. According to Lenhart, Kahne, Middaugh, Macgill, Evans, and Vitak (2008), the number one source for entrainment of 12-17 year old students was video games. Their study on American teenagers showed that 97% of teens play video games, with 50% of them playing at least once a day. Increasing technology improvements have made video games highly realistic and engaging which appeals to the technology-dependent generation. K-12 students do not want to read books or do homework assignments; they just want to play their video games. The fun, challenging, and competitive nature of video games motivate students to want to play them every day (Prensky, 2004). Educators should be taking advantage of the desire of students to engage with video games. If video games are popular among students, why not introduce serious gaming as part of the classroom instructional methodology?

As indicated by Westera, Nadolski, Hummel, and Wopereis (2008), if done correctly, serious games have the capability of presenting the educational material in a way that is more engaging than traditional classroom instruction. Rankin and Vargas (2008) found that students find boredom in the traditional classroom and that serious gaming can offer a fun and engaging environment. Serious gaming offered the motivational boost that students have been looking for (Rankin & Vargas). The ability to relate to video games makes the students excited about the topic (Rankin & Vargas). The positive results of serious gaming were noted by Mayo (2009). Mayo's research indicated that instruction with video games yielded up to a 40% increase in student learning over traditional lecture instruction.

However, the current push on serious games focuses mainly on the educational content of the game while overlooking the engaging parts which make the video games fun for students (McMahon& Ojeda, 2008). Educators are focusing on shoving the educational content in a game by sacrificing the gameplay and engagement. The idea behind this way of thinking is that if the educational content is in the form of a game, this means that it will be appealing to the students. Serious games created with this mindset are unappealing to the students (McMahon& Ojeda, 2008). Instead of using the serious games as the main form of instruction, the games should be used as an educational aid with pre-existing traditional instruction to engage and motivate today's students. The serious games should be developed to align with the content of the traditional instruction. The serious games need to be integrated with the existing curriculum, instead of being just an addition. Traditional instructional methodology will need to focus on the learning aspects and the serious game on the engagement factor which will motivate the students. For a serious game to be appealing, the fun and engagement needs to be in the forefront with the education aspect well integrated with the gameplay and narrative (McMahon& Ojeda, 2008). This balanced instructional method will ensure that the topic is both educational and engaging enough to motivate the students to learn in class.

Conclusion

Based on the discussions in this article, there is a problem with the current instructional methods that are used in the K-12 educational system. Traditional instruction is outdated and does not provide the motivation incentives for the technology-dependent generation to achieve academic success. The current generation of students spends a third of their day using some kind of electronic medium (Chaves and Anderson, 2008). Mediums like television, the Internet, and video games have become the main source of information and entertainment for today's youth. This dependency on technology has made traditional classroom instructional activities such as one-way teacher lectures, textbook readings, and written homework assignments less effective. A different instruction approach in the K-12 school is needed to accommodate the technology-dependent generation. A possible solution proposed by this paper is to use video games, which have become a popular source of entertainment for today's youth, into the classroom as instructional aides. These serious games have the capability of providing the needed motivation boost with their fun and engaging gameplay. However, it is not as simple as merely inserting a video game into the curriculum and hoping that it will increase the students' motivation and academic success. For a serious game to work, the video game needs to be developed with content that matches the traditional instruction that is being used in the curriculum. The video game needs to be be well integrated the same way PowerPoint slides are integrated with a lecture. Serious gaming will give a well-balanced instruction which contains the desired educational material as well as the motivational boost that is needed for the technology-dependent students.

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The Gary Plan: A Model for Today's Education?

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The term at the top of recent years' educational and legislative discussions at all levels is "education reform" (U.S. Department of Education, 2009). National, state, and local governments are all trying to enact laws and regulations to make schools change to better serve their students (Sokol, 2011). Their goal is to teach students skills that will help make them more productive citizens and keep the country on top industrially and economically (U.S. Department of Education, 2010). Technology education classes are being deleted from school course offerings because of either financial limitations or their perception as non-essential (Starzyk, 2009). Legislatures, parents, teachers, and educational leaders are sharing their opinions with anyone who will listen about what they think is wrong, and what they think will fix all these perceived problems with K-12 education (Wyatt, 2011). News publications and public policy agencies are noting that students need to learn the skills to keep the nation competitive, students need more hands-on and problem-based learning for the world of tomorrow, and that funding issues are inhibiting what can be accomplished in the classroom (Asia Society, 2008; Martinez, 2011; Williams, 2011). Are these aforementioned issues new concerns that are just now being discussed in our educational environment?

In reality, the above mentioned concerns, proposed fixes, and questions asked were being discussed in the early 1900's, where financial constraints and lack of skills being taught to students were major anxieties throughout the country as the United States entered the 20th Century. These concerns led to the creation and implementation of the Gary Plan of "work-study-play" by William Wirt in Gary, Indiana, in 1907 (Lipping, 2008). This plan led to an innovative way to implement and encourage the manual arts (a precursor to technology education) in K-12 education, and had students participating in hands-on activities that provided them with problem solving and career-related skills that could continue our nation's supremacy in that era. Today, the implementation of a few of the elements of the Gary Plan of study could not only alleviate some of the problems K-12 education is experiencing but could also greatly improve current technology education programs.

Wirt's Gary Plan

In 1907, Wirt became superintendent of schools in Gary, Indiana, a booming steel town located in northwest Indiana on Lake Michigan, and he immediately began implementing his educational reform plan on the local school system (Lipping, 2008). Wirt's philosophy, or the Gary Plan, was that the public schools should provide an oasis to instill the values of family, work, and productivity among urban students and produce an efficient, orderly society of solid, productive citizens (Cohen & Mohl, 1979). The core of the schools' organization in Gary centered upon the platoon, or work-study-play system. Wirt initiated new teacher hiring standards, designed the new school buildings that would accommodate his groupings of students, lengthened the school day, and organized the schools according to his ideals. The Plan theoretically organized students into two groups, or platoons. During the morning, Platoon A students occupied the specialized academic classrooms (mathematics, science, English, history, etc.), while Platoon B students were in the auditorium, shops, gardens, swimming pools, gym, or playground. They switched facilities during the afternoon. The students were busy all day, every day, and through this system were supposed to develop their mental, social, cultural, and physical abilities (Rich, 1992).

Gary's elementary schools were a beehive of activity where children not only learned math, history, and science, but also tended gardens, fed and took care of animals, and acquired demonstrable skills through hands-on activities in the vocational shops (WirtAlumni.com, 2010). Wirt was a firm believer in manual arts, the forerunner to technology education. The inclusion of manual arts into the regular school day curriculum gave elementary students the opportunity to become familiar with the industrial shops and practices by observing older students at work. Many of the older students were in the school shops building desks or bookcases, repairing items, or doing all the school's printing needs. Girls were also expected to participate in these shop environments, doing what they could do according to their strengths and abilities.

The platoon system gained acceptance in Gary and received national attention during the early decades of the 20th Century. Despite a failure of acceptance in New York due to political reasons, Wirt's system continued to achieve popularity during the 1920s. In Gary, the schools grew rapidly to serve the growing population and enrollment. As the city grew, so did school buildings, staff, and funding with the higher demand for education in the city. Outside of Gary, over 200 cities in 41 states experimented with the platoon system, and in 1925, the

National Association for the Study of the Platoon or Work-Study-Play School Organization formed to publicize the advantages of the platoon system (Cohen & Mohl, 1979). Wirt not only received national recognition for his plan, but also gained worldwide recognition in Europe to Japan.

How Gary Plan Elements Could Help K-12 Education

In today's K-12 educational climate, something has to be done to alleviate some of the curricular and financial burdens that are plaguing school districts, teachers and students. Implementation of elements of the Gary Plan could help alleviate some of the issues schools face. Utilizing elements of the Gary Plan's work-study-play system will help schools and teachers better meet the needs of all students. Gifted learners are one type of student that the Gary Plan could focus on through differentiated active learning. A differentiated classroom is one in which a teacher provides different avenues to the content (what is taught), the process (activities through which students come to understand what is taught), and the products (how a student shows what he or she has learned) in response to the readiness levels, interests, and learning profiles of the full range of academic diversity in the class (Tomlinson, 1995). Through differentiated learning, students who are gifted and are usually "bored" with the traditional teaching will be given opportunities to work on different projects that will stimulate their learning. Gifted students at higher class levels can use their time to instruct younger students in projects and activities, and feel that they are putting their time to good use. Slower learners in this setting can be made to feel better about themselves and their abilities through the hands-on activities of a Gary Plan classroom. These slower learners, whether it is because of low self-esteem, reading, writing and math difficulties, or low –

English language skills, are given opportunities to succeed while problem solving and working collaboratively with others. These students would have other students as mentors, either older students or classmates, to lead them through the learning activities of the day, and if these are done correctly, the students can be led to success. Sometimes these small successes are what it takes to engage a student in the learning process in the classroom.

At the elementary level, students wouldn't have to be made experts in anything during the time of active learning, but getting up and learning through an active learning activity can possibly help students learn better in the traditional classroom setting (Bonwell, 1991). Developmentally appropriate elementary practice is "based on knowledge about how children develop and learn" (National Association for the Education of Young Children, 1996). According to the Southern Regional Education Board (1994), a developmentally appropriate elementary program emphasizes the following:

- Active, senses-based exploration of the environment.
- Self-directed, hands-on learning activities balanced with teacher-directed activities.
- A balance between individual and group activities.
- Regular and supportive interaction with teachers and peers.
- A balance between active movement and quiet activities.

These concepts are either very evident in the Gary Plan, or can be easily incorporated into elementary classrooms based on elements of the Gary Plan. Gifted students in the regular classrooms at the elementary level will be much more involved in their own learning through the project-based elements of the Gary Plan. Project based learning is an instructional approach built upon authentic learning activities that engage student interest and motivation. These activities are designed to answer a question or solve a problem and generally reflect the types of learning and work people do in the everyday world outside the classroom (The Buck Institute, n.d.). This concept of teaching and learning is exactly what many feel is lacking in the way schools teach students today. During their time outside the traditional classroom, students can participate in their own learning through problem-based learning activities according to their own abilities, and acquire some elementary problem solving skills as a foundation that will help them as they continue their education.

How Gary Plan Elements Could Help Technology Education as A Discipline

The most exciting part of the Gary Plan for technology education is that it gives elementary students time every day to actively partake in hands-on, problem-based learning at a time when educational habits are being formed. Instead of waiting until they are older, elementary students can be exposed to many exciting technologies, and their parents can become more accepting of their need in knowing about these technologies in our ever changing world. Over the past decade, the *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association, 2000) and its subsequent updates and addenda have given technology education core standards for schools and teachers to strive to implement in their technology classrooms. Some would argue that with these *Standards*, finally technology education can begin to become more universally accepted by schools as an integral part of a student's total curriculum, and its teaching shouldn't be relegated to an afterthought or elective. Wicklein (2004) stated that there is a lack of agreement amongst teachers and university professors about what the curricula content of technology education should be in schools, despite the availability of the *Standards*. Will the *Standards* become another educational fad? By implementing more of the hands-on learning elements of the Gary Plan at the younger ages through elementary technology education activities, students are exposed to these *Standards* very early, and schools districts, teachers and parents are more accepting of them as important aspects of a total student's early education. Elementary students today are becoming just as immersed throughout their day in technology as their older siblings, and, provided through elements of the Gary Plan, being given this time in an elementary student's schedule to infuse the use of the *Standards* will help with their acceptance in educational circles.

As financial budget cuts in education have become the norm, many school districts are eliminating their "elective" or "exploratory" courses in the high school and middle school levels, and replacing them with "core" subjects such as language skills, math, and science. Across the nation school boards facing financial troubles are reverting to include curriculum consisting of only what courses the state requires and/or tests (Starzyk, 2009). Another reason for these elective cuts is the low scores on state tests that only test these core subjects, and administrators feel that students need more time and exposure to the core classes to better these scores (Primeau, 2003). This elimination of courses such as technology education is being done to the extreme detriment to a student's overall education. Many young students will now not have the opportunity to explore interests or develop new skills that will help then in secondary school or university work. Primeau (2003) indicated that New York State United Teachers spokeswoman Denise Clapham noted,

> Middle school students - who are at a very important intellectual time, coinciding with the kid's greatest physical, hormonal, and emotional changes - should be

> exposed to as much exciting, thought provoking challenges as they possibly can as well as the three R's.

As with growing acceptance of the *Standards* with administrators, teachers, and parents, implementing more of the hands-on learning elements of the Gary Plan at the younger ages can create a growing acceptance and agreement that technology education is a very important subject to be exposed to at an early age and that it should rank right up there with math and science as a core subject.

Conclusion

The Gary Plan, if it had been persevered and been expanded on in the 20th Century, had the potential to both change how younger students learn and be a very powerful and effective force on how technology education is perceived by education today. When implemented, the Gary Plan had all older students engaged in a form of technology education, schools better utilized all their facilities for student learning, and there was articulation between elementary and secondary programs. It was also ahead of its time with students actively engaged in hands-on, project-based learning. Infusing manageable elements of the Gary Plan today can help ease overcrowded schools, and can help schools meet the needs of all students through different levels of experiential activities. More set aside time in a school day to engage elementary students in technology education activities can raise the public awareness of the potential of technology education as a core discipline, which will hopefully lead to more schools valuing it and doing whatever it takes to salvage technology education courses when forces conspire to remove them as electives.

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Career and Technical Education Teacher Shortage: A Successful Model for Recruitment and Retention

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Abstract

The role of Career and Technical Education (CTE) as a major source of skilled workers for the American economy and a vital component of American education is well established. Several recent studies show that when CTE programs combine rigorous academic standards and industry-based technical content, the result is higher academic achievement and better economic outcomes for an increasing number of high school students. In spite of the documented successes and achievements of CTE high schools, studies show that many high school programs are faced with serious challenges, not the least of which is the difficulty in attracting qualified CTE subject teachers. This article examined one highly successful CTE teacher recruitment effort in New York that involves the

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city department of education, the teachers union, and a public university. The article focuses on the key elements of the teacher training program as a model for effective CTE teacher recruitment and retention.

Background

Career and Technical Education (CTE) has been a mainstay in the American education system for the past century. Looking forward, it is clear that the journey ahead will be very different from the one already traveled. For CTE to continue to be a relevant and major contributor to the successful lives and careers of students, many challenges must be addressed and overcome. Primary among these challenges is the need to provide highly qualified and highly competent CTE teachers who are able to prepare students to be successful in their careers and in their lives. In an effort to highlight and address this challenge, the Association for Career and Technical Education (ACTE) dedicated the January 2010 issue of its official publication, *Techniques* (Volume 85, No. 1), to the problem of CTE teacher recruitment and retention.

The purpose of this paper is to examine one highly successful long-term CTE teacher preparation effort in the New York City Public School system. We will first briefly examine CTE from a national perspective, noting recent trends in the field. Secondly, we will report on the status of CTE education within the New York City Public School system. We will then focus on the Success Via Apprenticeship Program (SVA), a unique and valuable cooperative endeavor between the New York City Department of Education, the United Federation of Teachers (UFT), and the City University of New York (CUNY). We will conclude with recommendations for the future.

National Trends in CTE

From a national perspective, Kazis (2005) in "Remaking Career and Technical Education for the 21st Century" draws several broad conclusions about CTE in the United States. Kazis notes that, while shrinking, CTE remains a significant component of the U.S. high school experience and appears to help less motivated and at-risk students stay in school and graduate. He further notes that the overall rigor of technical education in high school has improved, but there is more to do and many obstacles to overcome. Kazis's (2005) article which was supported by the Bill and Melinda Gates Foundation and the Ford Foundation refers to a consistent message that runs through seven short essays which comprise the work. The message is:

> CTE at the high school level must either change or die. Change may mean shrinkage in absolute size. It will certainly mean shifts in the kind and range of programs offered students and in the expectations placed on students, faculty, and administrators. The future may be different in urban and suburban regions, where the economic bases and the educational resources available for CTE can be quite different. The future is also likely to vary with the differential ability of state and regional CTE systems to meet rising expectations for quality and performance (p. 3).

The author notes in conclusion, that the greatest influence on CTE will come from the politics of education reform in the states and nationally, as well at the kinds of pressure and support the stakeholders for CTE and other reform movements bring to bear on public opinion and on the educational establishment.

In a related article, Medrich (2005) notes that for CTE to remain valued, certain steps must be taken. The steps include combining career-focused education with a strong academic core; removing less compelling program concentrations and eliminating weak course offerings. In addition, focus must be placed on the fundamentals, such as, creating an engaging curriculum; developing instructional strategies that are appropriate to the subject matter; providing support for students less prepared for rigorous coursework; and designing quality assessments. The overall national focus centers on improving the quality of CTE by employing new and creative approaches to the content and process of career and technical education.

CTE Teacher Shortage

The shortage of CTE teachers in the United States is a significant problem. Documented shortages exist in various states across the country. The state of Michigan, in a July 22, 2009 letter from Governor Jennifer Granholm, issued an exemption to retiree earnings in areas of critical shortages for 2009-2010 which includes numerous CTE position designations. In Virginia, the State Dept. of Education has designated Career and Technical Education a critical teacher shortage area since 2003. Other states that have identified CTE as a critical teacher shortage area include South Dakota, Iowa, and New York. Pytel, (2008) in the article "Shortage of Vocational Workers" notes the coming shortage of skilled vocational workers and comments on efforts by Des Moines (Iowa) Area Community College to address this need. On the website "Technology Education in Connecticut" (Kane, 2009) reports that the CTE teacher shortage undermines career and technical education and could potentially impact economic growth.

In the policy brief, "Teacher Shortage Undermines CTE" (Connely, 2009) notes that there has been an increase of almost six million students in CTE courses in just seven years, yet many existing teacher education programs have been eliminated. The number of CTE teacher education programs fell from 432 to 385 (from 1990 to 2000)—a decrease of 11%. Also, there is a growing number of teacher retirements affecting the supply of CTE teachers. In 2009, the National Commission on Teaching and America's Future estimated that "during the next four years, we could lose a third of our most accomplished educators to retirement." Several states, including Oregon, Alabama, New York, and California, to name but a few, are already engaged in unique and creative ways to address this critical shortage. Kiker and Emeagwali (2010) profiled programs designed to address the problem in several states including Kentucky, Missouri, Nebraska, North Dakota, Oklahoma, South Carolina, Texas, Utah, Washington, and Wyoming. Reese (2010) reviewed the different pathways that states have used to meet their needs for qualified CTE teachers. Reese noted that both traditional CTE teacher preparation programs and alternative programs that recruit industry career changers can prepare future teachers to the highest quality by employing experienced teachers as mentors and models of excellence.

New York State has been active in addressing the CTE teacher shortage in a variety of ways since the mid-1980s. Currently, there are three pathways to obtaining CTE teacher certification in the State of New York. The first pathway requires successful completion of an approved CTE teacher preparation program. There are only three such approved programs in New York State public universities, namely, New York City College of Technology of the City University of New York in Brooklyn; the State University of New York at Oswego; and Buffalo State College of the State University of

New York in Buffalo. The second pathway which is an alternative route to certification is known as Transitional A for career changers. The Transitional A certificate authorizes a school district to hire an individual with at least four years of experience in the trade to begin teaching while completing the requirements for the initial teaching certificate. The initial certificate requirements including a few college courses, a certification test, and mentoring all of which must be completed within three years. The third pathway to CTE teacher certification is through Individual Evaluation. In this pathway, a prospective CTE teacher who meets the minimum certification requirements including trade experience, college course work, and the certification test, submits his or her credentials to the State Education Department for evaluation and certification. In addition to the pathways already mentioned, individuals may also apply and receive New York State certification as CTE teachers if they are from a U.S state that has Interstate Reciprocity with New York, have non-U.S. credentials; or possess the National Board Certification.

New York City's CTE Teacher Recruitment and Retention Model: The SVA Program

For over two decades, New York City has been successful with recruiting and retaining CTE teachers through a unique program known as the Success Via Apprenticeship (SVA) Program. The SVA program, originally called the Substitute Vocational Assistant Program, was established in 1984 as a collaborative project of the New York City Department of Education, the United Federation of Teachers (UFT) which is the teachers' union, and the City University of New York (CUNY). The program was designed to prepare highly motivated graduates of CTE high schools to become CTE teachers. It is a comprehensive five and one half year experience that includes three components, namely, a salaried teaching internship, college level academic study, and relevant work experience in industry. The program specifically seeks out candidates from minority populations, including young women, who are pursuing careers in non-traditional trade and industrial occupations such as electrical installation, automotive maintenance, and heating, ventilation, and air conditioning (HVAC) maintenance.

Participant Eligibility and Selection

Prospective participants of the SVA program must be recent graduates of a New York City CTE or comprehensive high school. An applicant must be recommended and nominated by his or her trade teacher and selected by a selection committee of the school headed by the assistant principal for CTE. Priority is given to applicants who come from minority groups in terms of race, ethnicity, or gender (males or females pursuing non-traditional careers). Each applicant must have an outstanding academic record and be eligible for admission to the City University of New York (CUNY) either by virtue of Regents test scores, Scholastic Aptitude Test (SAT) scores, or passing CUNY’s basic skills tests of reading, writing, and mathematics.

At the beginning of each recruitment cycle which is usually in early spring, application forms are sent to CTE schools soliciting applications especially in those subject areas of current or foreseeable teacher shortage. Selection of applicants in each high school is done by a committee including trade teachers, building administrators, and representatives of the teachers’ union. Selected applicants are required to apply to CUNY and pass the CUNY basic skills tests in reading, writing, and mathematics unless they have received satisfactory scores in the Regents examinations or the

SAT. Applicants who meet testing requirements are scheduled for an interview by SVA program administrators. During the interview, an important eligibility criterion is that the applicant must demonstrate interest in becoming a teacher of his or her CTE trade subject.

Program Components

The SVA program is composed of a Teaching Internship, Industrial Work Experience, and Post-Secondary Academic Study. In the teaching internship component of the program, participants spend five months in a CTE high school during each year of program enrollment. While in the school, the SVA is assigned to a mentor teacher under whom the intern learns about unit and lesson planning, lesson presentation, classroom management, and school dynamics. Right from the first year, the intern is given ample opportunity to plan and teach lessons under the guidance and supervision of the mentor. Each intern is required to teach for one full semester under supervision during the third or fourth year to fulfill the student teaching requirement for State certification.

Career and technical education subject teachers seeking the initial teaching certificate in New York State must have a minimum of four years of full-time work experience. In order to meet this requirement through the work experience component of the SVA, participants are placed with employers in business and industry in work environments that match each participant’s career or trade area. Over the years, program administrators have developed a network of employers in business, industry, and government agencies as job sites for placement of participants. These include automotive service shops, electrical contractors, electronics and computer service companies, hospitals, and museums, among many others. Each participant completes seven months of work experience in his or her trade during each year of program. The work experience is supervised by on-the job trainers and closely monitored by a program administrator who makes regular visits to the job site to evaluate the participants' progress.

In the post-secondary academic study also known as the college component; participants are enrolled in teacher education courses at New York City College of Technology. Each participant is required to complete 44 credits of coursework during the five and one half years in the program (a total of 62 credits is required for State certification). The curriculum consists of courses in liberal arts and sciences, professional courses in career and technical education, and student teaching.

Program Uniqueness

Program administrator involvement and monthly meetings are among the unique aspects of the program. Program administrators handle the recruitment, interviews, placement, and supervision of participants in school and job sites. They conduct regular school site and job site visits and evaluations of all participants. In addition, program partners, administrators and participants meet during mandatory monthly meetings. Administrators deliver reports on various components of the program including school sites, work sites, etc. The college representative also reports on general college and academic matters affecting participants. At each meeting, a selected group of participants make presentations on topics of interest to them. The required dress code for all participants is business attire.

Elements of Program Success

The SVA program has been very successful in recruiting, preparing, and retaining young CTE teachers in the

New York City public high schools. This success is attributable to four key factors, namely, compensation, contractual commitment, administrator involvement, and high performance expectations. The high schools from which participants graduate play a crucial role in identifying students who have the interest and potential to succeed as CTE educators. By working with the schools, SVA program administrators not only know subject areas where there are potential shortages, they are also able to project need and identify potential replacements. While enrolled in the program, participants are paid 90% of the contractual salary rate for a starting teacher (currently $45, 000 per year). The salary rate is very competitive and, in some cases, far exceeds what a recent college graduate earns in certain jobs and, certainly, the annual salary of a high school graduate. As employees of New York City Department of Education, program participants are also eligible for many of the benefits that a certified teacher is entitled to under the teachers' union contract, including pension, health, dental, and optical insurance, as well as annual leave benefits. Successful program completion also means a higher salary step at initial full-time employment as a certified teacher.

The SVA program pays participants' college tuition and fees for course work leading to the New York State initial teaching certificate. Many participants take advantage of this educational opportunity and complete the Bachelor of Science in Education (B.S. Ed.) degree within the five years of participating in the SVA program.

In return for all the benefits of participating in the SVA program, each participant is required to sign a letter of commitment to work for five years as a CTE teacher in New York City public schools. If a participant who successfully completes fails to meet the contractual obligation to work in New York City, the Department of Education has the recourse to seek reimbursement of all tuition and fees paid on behalf of the participant.

The SVA program has very high standards of performance and conduct in all three components. Participants must receive excellent evaluations by school site mentors, college supervisors, and work site supervisors to maintain their status in and successfully complete the program. In the college component, for example, participants are held to the same academic standards as other degree-seeking students of the teacher preparation program. They must maintain a minimum grade point average of 2.50 in college courses or risk being dismissed from the program. Participants who receive poor evaluations in any of the three components of the program are brought before a personnel committee which handles all disciplinary problems and is comprised of program administrators and representatives of the teachers' union. If a participant is found to be not meeting program standards of performance or conduct, he or she is placed on probation and given an opportunity to improve within one academic semester. If there is no improvement after one semester, the participant is dismissed from the program.

Regarding evaluation of the overall program, the most recent data indicates that the program has been highly successful. In the last five years, 36 SVA Interns have graduated from the program. Thirty-four (94.4%) were offered and accepted regular teaching positions. Of the 34 that accepted teaching positions, 33 (94%) are currently teaching.

SVA Program Limitations

Although there are many obvious benefits to the program, some limitations do exist. The most significant limitation to the program's operation is cost. Considered as a whole, the overall salary and associated employee benefits cost to the program are substantial. Related administrative costs are also incurred on an annual basis. The other primary limitation of the program involves order of magnitude. The number of program completers is relatively small (due to cost constraints) which means that the need for certified CTE teachers in the overall New York public school system is met in a small, incremental manner.

Future Directions

Successful efforts like the SVA Program can have a major positive impact on the current and future recruitment and retention of qualified CTE teachers. In the future, cooperative efforts between industry and education can yield positive results while at the same time address the cost issues associated with programs such as these. There can be creative approaches to encourage students to pursue careers in teaching CTE subjects. One suggestion could be to attract students with associate degrees in technical areas by offering tuition assistance for the education courses required for certification. A concerted effort could be organized on a state by state basis to actively recruit students pursuing technical associate degrees and provide full or partial tuition assistance support as they pursue their teaching certification. Also, much can be done in the way of simplifying the bureaucracy surrounding the CTE certification process. There are untapped pools of technical talent in industry and the military. If the process to certification were streamlined and made more user friendly, there could be a significant increase in talented and productive CTE teachers.

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Selected Core Thinking Skills and Cognitive Strategy of an Expert and Novice Engineer

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Introduction

Understanding how students learn engineering design concepts and the subsequent instructional interventions that are directed to improve their performance is also contingent on understanding how experts in the various engineering disciplines solve engineering problems. Naturally, a part of the engineering and technology educators' research agenda is aimed at gaining a better insight of how student and expert engineers solve specific engineering problems. This hopefully would lead to a larger body of knowledge that is accessible for administrators and teachers to make informed decisions about the teaching of engineering design concepts.

Over the past two decades a steady proliferation of studies in engineering problem solving have focused on the differences between expert and novice designers (Cross, 2002, 2004), design reasoning and thinking (Goldschmid & Weil, 1998), creativity and design (Christiaans & Venselaar, 2005; Dost & Cross, 2001) and the design processes and strategies of engineering students (Atman & Bursic, 1998; Cardella, Atman,

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Turns & Adams, 2008; Merrill, Custer, Daugherty, Westrick, & Zeng, 2007). In a recent study by Merrill et al. (2007) three core engineering design problem solving concepts were identified as important to teach at the high school level—constraint, optimization, and predictive analysis (COPA). These concepts reflect the processes that the professional designer uses in the real world to solve design problems. The ill-structured nature of engineering design problem solving also demands the use of high level thinking skills such as analyzing and generating skills (Ullman, 2003; Atman & Bursic, 1998). These skills are inextricably linked to the strategies used by experts and novices as they work with the constraints of a design problem, find an optimal solution, and use various analytical procedures.

When engineering design is examined from the perspective of the problem space and solution space (Dorst & Cross, 2001), these two mental spaces represents spaces of association between core thinking skills and core engineering design processes such as COPA. The problem space includes activities such as defining the problem, identifying constraints, specifying evaluation criteria, and gathering information about various solutions. The generation of solutions and the execution of problem solving strategies define the solution space. Specifically, this includes activities such as making decisions about various possible solutions, performing analysis, optimizing the selected solution, and determining specifications.

Purpose of the Study

The purpose of this study was to use verbal protocol analysis to explore qualitatively how the analyzing and generating thinking skills of a student and an expert engineer differ, and to determine how these core thinking skills influences their overall cognitive strategy in the problem and solution spaces as they solved a common engineering design problem.

Research Questions

The following research questions guided this study:

1. How do the analyzing skills of a student and an expert engineer differ when using core engineering design concepts in solving a design problem?
2. How do the generating skills of a student and an expert engineer differ when using core engineering design concepts in solving a design problem?
3. What are the dominant cognitive strategies used by the engineering student and the expert engineer?

Thinking Skills, Design Concepts, and Design Strategies

Core Thinking Skills

Researchers identified several core thinking skills that are used by individuals in cognitive processing and for creative and critical thinking. These skills are valued by educators as important for learning and problem solving (Marzano et al., 1988). They are grouped into eight categories: focusing skills, information gathering skills, remembering skills, organizational skills, analyzing skills, generating skills, integrating skills and evaluating skills. For the purpose of this study, analyzing and generating thinking skills were examined because these skills constitute key cognitive activities of engineers when they solve design problems.

As engineers solve problems, they generate various types of conceptual solutions and perform analyses using different mathematical strategies and heuristics (Ullman, 2003). According to Marzano et al. (1998), “analyzing skills are used to clarify existing information by examining their parts and relationships” (p. 91). To analyze, one must be able to identify attributes and components, identify relationships and patterns, and identify errors.

In engineering design, the ability to identify attributes and components helps students to focus analytically on the structure of objects, their systems, and forms. Identifying relationships and patterns allows students to recognize and articulate the interrelationship and the functionality of component parts. Several studies have examined the importance of identifying relationships and patterns. In a study conducted by Egan and Schwartz (1979), they found that the recall of circuit drawings by skilled technicians was remarkably similar to the recall of chess positions by expert chess players. They referred to this aspect of pattern relationship as chunking. In addition, they verified that experts are able to improve their memory and problem-solving capability by identifying conceptual relationships. This is in contrast to novices, who because of a lack of domain-specific experience arrange patterns according to positional relationships.

Ball, Omerod, and Morley (2004) conducted think-aloud protocols of expert engineers with a minimum of 7 years of academic and commercial design experience, and novices who were master's engineering students with limited design experience. Each participant received an identical brief that related to the design of an automated car-rental facility. This brief was designed "to be complex, multifaceted, and ill-defined in the traditional sense of a prototypical design problem but tractable enough to be tackled to a satisfactory level by designers with only a few years of design experience" (p. 502). They found that experts displayed greater evidence of analogical reasoning than do novices, irrespective of whether such analogizing is "schema-driven" or "case-driven." Schema-driven analogizing involves "the recognition-primed application of abstract experiential knowledge that could afford a design solution to a familiar problem type" while case-driven analogizing entails "the invocation of a concrete prior design problem whose solution elements could be mapped onto the current problem." They also found that the expert designers showed more evidence of schema-driven analogizing than case-driven analogizing, while the novice designers showed more evidence of case-driven analogizing than schema-driven analogizing. In other words, expert designers are more proficient in recognizing design problems with similar underlying conceptual relationships than do students or novice engineers.

Identifying errors, the third analyzing skill, involves detecting flaws that may exist in knowledge, logic, calculation, or procedure. This analysis also extends, where possible, to actions that identify the causes and make corrections where necessary (Marzano, et al., 1988). It is often postulated that people use mental models or their own naïve theories to help them understand how complex systems behave (Gentner 2002; Collins, 1985). These mental models and theories assist in the diagnosing of error. Because of their experience, experts have more sophisticated causal mental models and theories that are governed by concepts from several related domains (Kempton, 1986) and so they are naturally more efficient at identifying errors in their design conceptualizations.

Generating skills enables an individual to use prior knowledge to add information beyond what is given (Marzano et al., 1988). The student therefore uses his/her knowledge of the sciences, technical drawing, and the function of mechanisms to generate or construct a new device or system. This cognitive process involves connecting new ideas with prior knowledge to build a coherent organization that houses both new and old knowledge structures, which represents the interpretation of a new situation. Generating skills involves inferring, predicting, and, elaborating. Inferring involves deductive and inductive reasoning. Predicting is making a statement or expectation anticipating the outcomes of a situation based on prior knowledge of how things usually turn out. Elaborating involves adding details, explanations, examples, or other relevant information from prior knowledge to improve understanding. Elaborating can be complex and involves constructing mental models and analogies to understand the structural and functional features of objects and systems.

According to Bedard and Chi (1992), experts are more efficient and superior in classifying problems according to relevant features. They are also efficient in their inference about additional aspects of the problem. Experts represent problems according to their conceptual features, and spend a considerable amount of time developing their representation by adding domain specific and general constraints. In contrast, novices' representations are largely based on literal features and they may attempt to solve problems directly without properly defining them. The complex mental models that experts are able to generate make it easier for them to make accurate inferences and predictions, and elaborate about their solutions performance and the functionality of the designed component. Cross (2004) indicated that experienced designers use more generative reasoning in contrast to less experienced designers who use more deductive reasoning. In addition, expert designers select features of the problem space to which they chose to attend (naming) and identify areas of the solution space which they chose to explore (framing). Some expert designers (architects) approach to problem solving was characterized by strong paradigms or guiding themes, while novices had weaker guiding themes.

Core Engineering Design Concepts

Although engineers use various approaches and methods to solve design problems, three core engineering design problem solving concepts were identified as important to teach at the high school level—constraint, optimization, and predictive analysis (COPA) (Merrill et al., 2007).

Various types of analytical methods and models are used in engineering design to predict the performance of artifacts and systems. The applicability of an analysis method is dependent on the level of accuracy needed and the availability of sufficient methods. General analytical methods are less expensive and faster to implement than physical modeling methods (Ullman, 2003). Ullman gave an example of how the stiffness of a diving board can be determined by using a method from the strength of materials:

> …the board is assumed to be a cantilever beam made of one piece of material of constant prismatic cross section, and with known moment of inertia. Further, the load of a diver bouncing on the end of the board is estimated to be a constant point load. With this analysis, the important variable—the energy storage properties of the board, its deflection, and the maximum stress— can be estimated. (p. 264)

Predictive analysis should be carried out in the planning environment and not the task environment because moves made in the planning environment can be easily undone, while the task environment actions cannot be reversed.

In the initiation of a new design problem, the design requirements such as specification and conditions for function, effectively constrain the possible solutions to a subset of all possible product designs. As the design process continues, other constraints are added to further reduce the potential solutions to the problem, and potential solutions are continually eliminated until there is only one final product design (Ulman, 2003). Beyond the constraints of the original problem, constraints that are created during the design process come from the designer's knowledge of mechanisms, devices, and systems, and also from the design decisions made during the designing process. Other sources of constraints are costs, economics, feasibility, time, material, and environmental implications.

The purpose of optimization is to achieve the best design based on prioritized constraints and criteria. This includes maximizing factors such as productivity, strength, reliability, longevity, cost, efficiency, and utilization (Merrill et al., 2007). The functional parameters of designed components can be converted to some mathematical formula to determine the optimal functioning capability of the designed component.

Cognitive Strategy

Designers use different strategies to solve a design problem. For example, some designers may begin solving a problem by deciding whether the process should be one of design or redesign. Another group of designers may prioritize certain stakeholders and strategize their solutions around the high-priority stakeholders. Other designers may arrange their design assignment to be new and challenging in order to provoke a creative response (Dorst & Cross, 2001).

In a protocol analysis of nine experienced designers solving a design problem, Kruger and Cross (2006) categorized the strategies used into four general approaches. These are:

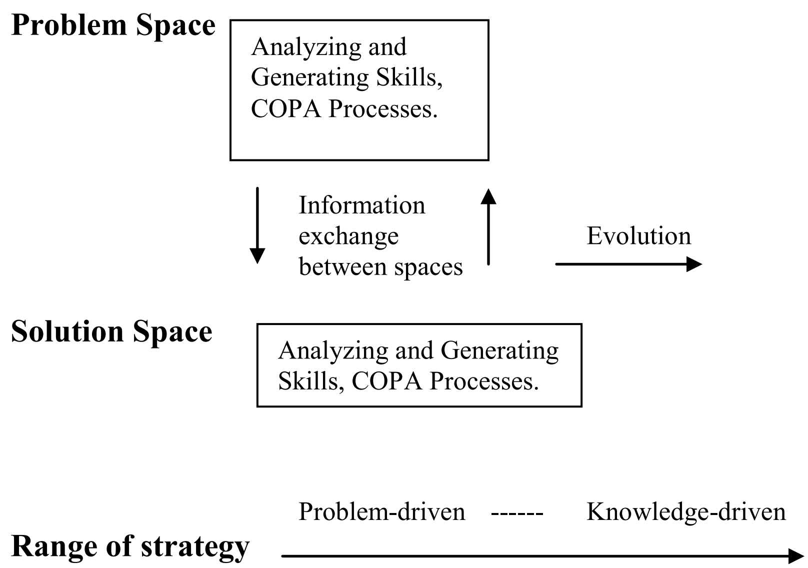
- Problem-driven design. The designer focuses closely on the problem at hand and uses only information and knowledge that are strictly needed to solve the problem. The emphasis lies in defining the problem and finding a solution as soon as possible.

- Information-driven design. The designer focuses on gathering information from external sources that have not yet been processed and develops a solution on the basis of this information.
- Solution-driven design. The designer focuses on generating solutions and gathers only information that is needed to further develop a solution. The emphasis lies on generating solutions, and little time is spent on defining the problem.
- Knowledge-driven design. The designer focuses on using prior highly structured, individual knowledge and develops a solution on the basis of this knowledge. Only minimal necessary information from external sources is gathered.

The Conceptual Framework

Figure 1 represents the framework that was used in this study. Analyzing and generating skills are used by designers in varying degrees as both mental spaces (problem space and solution space) evolve and as they work with various constraints, and carry out predictive analysis and optimization. This is illustrated in the diagram by the two ellipses. The design strategies used by each engineering designer will also vary and may include one or a combination of problem, information, solution and knowledge driven strategies.

Figure 1.
Conceptual framework



Verbal Protocol Analysis

A protocol is a "description of activities ordered in time, in which a subject engages while performing a task" (Hayes, 1989, p.51). Verbal Protocol Analysis (VPA), also known as "think-aloud" protocols, are often collected during (concurrent protocols) and after (reflective or retrospective protocols) problem solving episodes, to obtain a record of the knowledge used by the problem solver, and the succession of mental states through which he or she passes while working on the problem (Proctor & Dutta, 1995). When conducting a verbal protocol, the participants are asked to say aloud everything they think, while performing the task, no matter how trivial it seems. The obvious benefits of this type of analysis include the relative ease with which participants typically verbalize their thoughts, and the potential for insight into their cognitive processes. Once the verbal protocols are collected by audio and/or video, they are transcribed, segmented into codable units of subject statements, coded according to a coding scheme, and analyzed to answer specific research questions.

Think-aloud protocol has been used extensively in reading and comprehension studies (Donndelinger, 2005). Atman and Bursic (1998) argued that concurrent report is a valid method that can be used to collect data about someone's thinking process. However, some have expressed concern that think-aloud protocols may distort or interfere with the mental processes that we seek to observe (Proctor & Dutta, 1995). Others contend that when protocols are collected properly it does not distort or interfere with the participant's thinking and performance, because information is being collected from the short term memory, while subjects are prompted to "keep talking" with minimal interference from the experimenter(see Christensen & Yasar, 2007; Ericsson & Simon, 1993).

Verbal protocol analysis has also been used by several researchers in engineering design to understand the cognitive process of experts and novice designers (see Atman & Bursic, 1998; Ball, Ormerod, & Morley, 2004; Christensen & Schunn, 2007; Christiaan & Dorst, 1992; Cross, 2002; Dorst & Cross, 2001). A more recent study by Cardella, Atman, Turns, and Adams (2008) investigated the changes in individual engineering students design process over their course and how these changes might prepare them to become global engineers. Verbal protocol analysis was used to gain insight of the design behavior of engineering students as well as faculty members. A total of 61 students from various engineering disciplines participated. Some of their findings revealed that the more experienced designers (seniors) tend to spend more time in design activities such as evaluating design alternatives, making design decisions, and communicating design decisions. Senior engineering students had more complete design solutions. Their solutions also had additional mechanical and technical features. Finally, they found that differences in “the structure of the task may affect students’ use of ‘analytical skills’, their ‘holistic, multidisciplinary thinking’, their tendency to ‘exhibit creativity’, the extent to which they exhibit ‘high ethical standards and a strong sense of professionalism’ and their use of ‘the principles of business management’” (p. 257).

Methodology

Purposeful sampling was used with a multiple-case study design. According to Gall, Gall, and Borg (2007), in purposeful sampling, the goal is to select cases that are likely to be information rich with respect to the purposes of the study. In a multiple-case design, the unit of analysis is two or more individuals, or two or more instances of phenomena that are collectively studied in one case. For the purpose of this study two participants with significant differences in their years of experience were used—an experienced engineer and a engineering student. Verbal or “think aloud” protocols were collected from each participant as they solved a design problem within an artificial context.

The Participants

The novice was a senior mechanical engineering student who worked as a teaching assistant for a computer-aided design course. The expert had a Bachelor’s degree in mechanical engineering and over 28 years of work experience. This included working as a manufacturing engineer and a locomotive engineer. He is also recognized as an expert builder of large size locomotive models. That located him well above the number of years that it normally takes one to achieve expertise. According to Simon and Chase (1973), experts needed about 10 years of intense involvement in domain-specific activities before they can reach international levels of performance.

The Task

Each participant was given an ill-defined mechanical engineering design problem to solve. The engineering design problem was taken from a mechanical design text and modified to make it more ill-defined and more challenging. The task was then sent for validation to two engineering instructors, each with over 25 years of faculty experience teaching mechanical engineering. Feedback provided by each of the instructors resulted in minor modifications of the design task (see Figure 2).

Figure 2
The Design Task

Designing Task

Overview
The objective of this engineering designing activity is to understand better the cognitive process of engineering designers as they solve a design problem. The process that will be used is a Verbal Protocol Analysis. This means that as you solve the problem you will be required to **"think aloud"** (say aloud) what you are thinking. If you stop speaking I will remind you to resume speaking a loud as you solve the problem. The designing challenge below should not take you more than 1 hour to complete. The information from his activity will provide deeper insight in how to teach engineering designing and develop engineering designing curricula for K12 institutions.

The Task
Design a quick release hold – down device used for holding down work-piece in a wood or metal shop. The devise must be able to hold material up to 3 inches thick and have at least an 8 inch reach. It should have the ability to release the work piece quickly and should be easy to position and move to other work surfaces. The holding strength of the device should also be considered.

Procedure

Concurrent verbal protocols were collected from each participant as they solved the design problem. Verbal protocol analysis requires participants to "think aloud" while solving a problem or performing a task (Atman & Bursic, 1998). The novice (engineering student) selected a computer lab on campus to solve the design task while the expert used a drafting office at his home. Both were given pencils and sketch pads, and both were allowed to use the drafting software on their computer. They were each given an hour to complete the problem and were prompted to continue to speak aloud what they are thinking whenever they became silent. Each "think aloud" session was recorded digitally.

Data Analysis

After each participant completed the design task, the audio recordings of their concurrent protocols were transcribed. The transcribed protocols were then segmented into think-aloud utterances, divided into sentences, and coded. The quality of the sketches was not evaluated since the objective of the study was to examine the mental processes of the engineering student and engineers while solving the design task. The sketches and notes however, acted as a reference to clarify some sections in the protocols.

The purpose of segmenting is to break the transcribed verbal protocol text into units (or segments) that can be coded with a pre-defined coding scheme. Segmenting took place in two stages. In the first stage, larger units of analysis called *think-aloud utterances* were identified and segmented from each other. Think-aloud utterances are comprised of those words spoken aloud by a participant that were followed by some period of silence (Hartman, 1995). These periods of silence or pausing had to have duration of five or more seconds. A total of 70 utterances were segmented (40 for the engineer and 30 for the engineering student). The think-aloud utterances were further segmented into sentences.

Codes were provided for eleven predefined constructs. The constructs, their codes, and meanings are described in Table 1. Reliability coding was conducted by having one additional person code five pages of the first transcript. A reliability kappa coefficient of 0.86 was calculated which was well within the range recommended for interrater reliability (Miles & Huberman, 1994).

Table 1
Constructs, Codes and Definitions

Construct	Code	Definition
Analyzing Skill		
• Indentifying attribute and component	IAC	Make distinction between parts that together constitute a whole. e.g., The various parts of a nail gun.
• Indentifying relationship and pattern	IRP	Articulate the interrelationships between components. e.g., rotating wheel and a gear mechanism.
• Indentifying Error	IE	Detecting mistake in logic, procedure, calculation. Identifying an error in design e.g., recognizing a component won't work because of a design flaw.
Generating Skills		
• Inferring skills	IS	Going beyond available information to identify what reasonable may be true.
• Predicting skills		

	PS	Assessing the likelihood of an outcome based on prior knowledge of how things usually turned out. E.g., Shaft will wear because tolerance is too small.
• Elaborating skills	ES	Adding detail explanations, examples or other relevant information from prior knowledge to improve understanding. e.g., using knowledge of typewriter to know how a computer works.
Engineering Design Concept		
• Constraint	C	Specifications, criteria and conditions that constrains an engineering designing task. e.g.,
• Predictive analysis	PA	A device to clamp soft surfaces. Methods analyzing the functionality of a designed component. e.g., Calculating the maximum stress a device can withstand.
• Optimization	O	Obtaining the best design based upon prioritized constraints, and criteria.
Solution Space	SP	Generating solution
Problem Space	PS	Framing the problem

Results

Research Questions One

Table 2 illustrates that the student performed twice as much analysis as the expert. However there were differences between the student and the expert in where the analyses were primarily performed. The expert did most of his analysis (15) when using engineering science and mathematical formula.

The student, on the other hand, did most of his analysis (34) when he was resolving issues relating to the various constraints in the design problem. Both the student and the expert's analysis mainly focused on the relationships between the component parts of their design.

Table 2
Analyzing Skills Frequency Table

	Constraint	Predictive Analysis	Optimization	**TOTAL**
Analyzing skill of Expert				
Identifying attribute and component	5	4	2	**11**
Identifying relationship and pattern	5	8	2	**15**
Identifying error	0	3	3	**6**
TOTAL	**10**	**15**	**7**	**32**
Analyzing skills of Novice				
Identifying attribute and component	14	4	2	**20**
Identifying relationship and pattern	14	7	4	**25**
Identifying error	6	6	6	**18**
TOTAL	**34**	**17**	**12**	**63**

Research Question Two

Table 3 illustrates that the expert used almost twice as much generating skills as the student. Most of these skills were used primarily when he carried out analysis and optimization. In contrast the student did most of his generating when he performed analysis. The expert also spent more time making inferences and elaboration about the quality of his solution while the student spent more time predicting how each component will function.

Table 3
Generating Skills Frequency Table

	Constraint	Predictive Analysis	Optimization	**TOTAL**
Generating skills of Expert				
Inferring	2	13	12	**27**
Predicting	2	10	6	**18**
Elaborating	12	6	8	**26**
TOTAL	**7**	**31**	**26**	**64**
Generating skills of Novice				
Inferring	2	7	2	**11**
Predicting	6	8	4	**18**
Elaborating	2	4	4	**10**
TOTAL	**10**	**19**	**10**	**39**

Research Question Three

Verbatim reports from the transcripts of both participants' "think-aloud" session highlighted the strategy used by each to solve the design challenge. The comments are preceded by a timestamp.

The Expert

While the expert had over 25 years of experience, the type of task he was required to solve did not fall within the general type of problems that he was accustomed to solving. Immediately after reading the problem, the expert formed a mental image of the solution. He used this mental image to frame and plan the strategy he would use:

> (00:33) What I would probably do is I see a mental picture of that hold down device in my head. I would probably go with a design that was similar to that because I knew that was the design that has been proven to work so in a way. I'm not creating something from nothing. I've already got an idea what that would look like.

The expert used his experience and knowledge of moments and forces to resolve positional and functional issues and made decisions about the relationship and structure of the component:

> (03:03) I know that from experience there should probably be a lower pivot point. Just guessing at this point in time, so I'm going to sketch a lever that comes up that's pivoted and then there should be another connection from this lever, the lever on my arm that I'm using to raise and lower it. So now what I got here is some rough idea of the linkage. I think would work and then of course to hold this down to a clamping device. I have to realize that my lever here needs to go over center so the item that you're holding down cannot be the force, because it would not pull back and release itself. For instance, if I pivot this point here and I pivot this point back to here. What it is going to do to the lever that I install here is that it is going to actually pull back and lift this thing, or is it going to bind or

> whatever. I may have to have some spacers or something to bring it out around the other point and ah something like this.

The expert strategized his approach from a system perspective. He seemed to identify the most critical element of the system, and then focused his cognitive effort into solving the function of those components to meet his personal goal and the solution criteria:

> (10:00) …once I know my linkage is going to work and if I pull the lever, this thing is going to open up and whatnot like I want it to. Then I'll go to more of a design process where I actually may come up with, I guess, the second design of the parts that actually would work.

He also evaluated and reflected on his progress. If there was conflict with his approach and solution he considered alternatives, but his motivation to achieve his goal impelled him to use his experience or knowledge of physical principles to resolve the conflict:

> (25:00) …if I use these parameters I'm going to be able hold the part down or would the part just push back and just push these lever arms up? That I don't really know at this point in time. Should I start this thing all over again or is this going to be a good design? Should I go back to the paper or should I come up with an alternative holding device?

The Novice

The novice used more time (approximately 10 minutes) when compared to the expert (approximately 3 minutes) to analyze the problem, clarify elements of the specifications that he could not understand, and gather data, before he started generating solutions. His solutions were primarily influenced by the specifications identified in the problem.

> (00.34) …specifications are to hold three inches of material, and have eight inches of reach which is somewhat ambiguous. I'm interpreting that as meaning that it can extend eight inches from the material so that it can be gripped. To be able to solve this next part, to release the work piece quickly, easy to position, and easy to move to other work areas so it's not too overly bulky or too heavy …the holding strength should be considered. Okay so now the holding strength would depend on what type of material that we're going to be holding.

The solutions generated by the novice appeared initially to be limited to the concept of two moving parts. He then started generating solutions around the two moving parts using mental pictures and imposing constraints as he progressed.

> (03:23) …first thing that I'm going to do, I guess for something like this we're going to have moving parts. So I'll be designing probably at least two parts …would probably be the holding mechanism some sort of screw, that's what I'm interpreting … going to be able to adjust because we want to be able to let it grip below three inches, so it needs to have some sort of adjustment.

As the novice progressed, he used analogies that were case specific to decide on the structure of the component. This was evident at various points during his solution. He also spent time determining the relationship of one component with the other. As his solution progressed, it showed a component-by-component pattern of solution which can be compared to using bottom-up generation of solutions rather than a top-down:

> (06:33) …some kind of gripping mechanism on the top of the lever like some claws which is what we see on monkey wrenches…I'm going to design something

> similar for the bottom now except that this has to be able to interact with the screw to let it move up and down… am I thinking that this other part is actually going to be sliding up and down the long side of the part.

Like the expert, the novice also used knowledge of moments and forces to evaluate and resolve positional and functional issues and also to make decisions about the structure and relationship of the components. He also performed evaluation at various stages of his solution.

> (18:50)…I try to make use of symmetry so that it fits directly in the center. The last thing I would want to do is create offset forces in moments that could really mean it introduces bending stresses and that's just not something we want… Albeit a quick release mechanism something like this might be a little bit dangerous to have, which is perhaps why there aren't a lot of them....

Figures 3 and 4 illustrate the cognitive strategies used by the expert and novice respectively, as they navigate cognitively between the problem space and the solution space. The time spent in the problem space was determined by statements made by the participants when framing the problem

Figure 3
Network diagram for expert

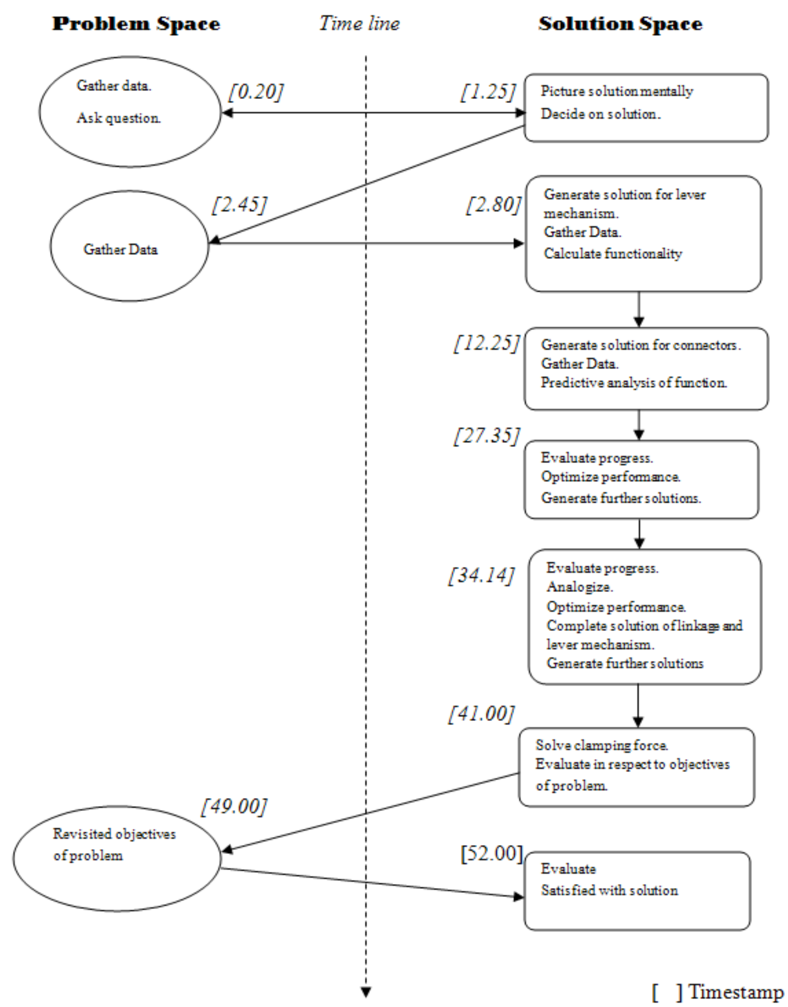
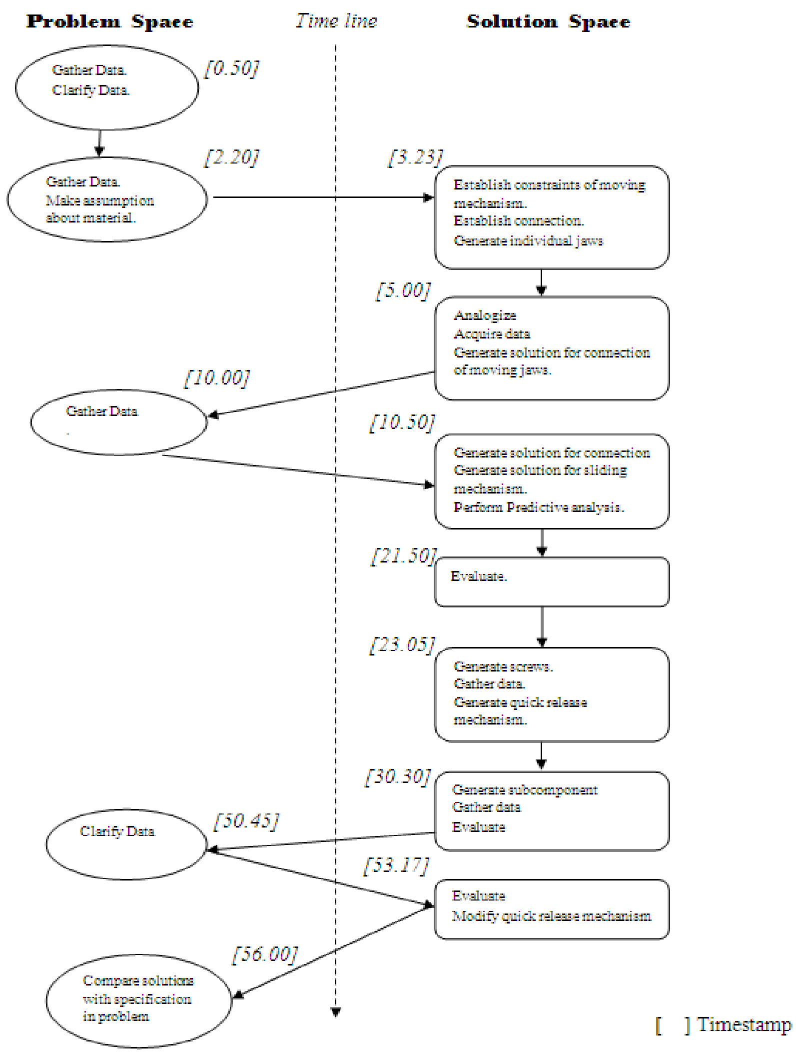


Figure 4.
Network diagram for engineering student



and gathering data about specifications and constraints, while time spent in the solution space was determined by statements made by the participants when generating solutions, performing analysis, and optimizing solutions. The network diagrams show that the novice spent more time in the problem space than the expert. It also shows that the expert framed his solution around his mental model, while the novice framed his solution around the problem specifications. The novice depended mainly on the information provided by the problem, thus proving that he used the problem-driven strategy. In contrast the expert used the solution-driven approach, spending most of his time generating solutions and little time defining the problem.

Conclusions

This exploratory study highlights certain differences in the way an expert and a novice engineer used their analyzing and generating skills while solving a fairly ill-structured design problem. The expert tends to use more inferences and elaboration when solving the design problem and the novice tend to use analysis that is focused on the functional relationship between the parts of the designed component. This difference might be attributable to the mental models or analogies that they generate. The mental representations used by the expert not only allowed him to go beyond merely predicting the performance of his conceptualization, but to also improve his solution by adding additional details that the novice, who because of his limited experience, was unable to add.

The novice behavior was associated with a “depth-first” approach to problem solving. This approach is characterized by sequentially identifying and exploring sub-solutions in detail. He approached the solution component-by-component, focusing on the adjustable jaws, then the screw, locking device, and lever. The expert in this protocol study showed a "top-down" "breadth first" approach, which is consistent with what research confirms of experts in some knowledge domains. He quickly recognized the system requirements and then focused his efforts on designing what he perceived to be the most critical element of the system—the lever locking mechanism. His approach might also be attributable to the fact that experts are exposed to a large number of examples, problems, and solutions that occur in their domain. Therefore a key competency of the expert is the ability to stand back mentally from the specifics of the accumulated examples, and form a more abstract conceptualization pertinent to the solution (Cross, 2004). This allows him to focus on the critical elements of the problem, rather than on superfluous details.

Both the expert and novice carried out frequent monitoring and evaluation of their strategy and solutions to identify errors. The novice however, evaluated against the specifications and constraints dictated in the question, while the expert evaluated against his perceived functional goals. The engineer used his initial mental models to guide his solution and displayed more complex inferring and elaborating skills. He also spent more time in the solution space. Lloyd and Scott (1994), reported that experienced designers used more generative reasoning, in contrast to deductive reasoning employed by less experienced designers. In addition, their protocol studies of experienced designers found that they were more solution focused. The expert's approach clearly was solution-driven. He selected a feature of the problem-space to attend (naming), and from there explored the solution space (Schon, 1983). The expert spends more time within the solution-space, while the novice spends more time within the problem-space (see Figure 3 & 4).

Finally, both the expert and novice in this study used knowledge of mechanics to evaluate and also predict functions and positional locations, as well as to identify errors. This was consistent with findings which showed that one of the commonalities between designers was their implicit or explicit reliance on 'first principles' in both the origination and detailed development of their design solutions (Cross, 2002).

Implications for Engineering and Technology Education

The findings from this study would suggest that a proper grasp of systems concept is necessary to raise the problems solving ability of students to be reflective of experts. How components interrelate with each other and to the entire system, whether it be a simple or a complex system, are important for students to understand in order to increase their ability to generate conceptual solutions and solve functional issues. This will enable students to spend more time in the solution space, like experts, rather than in the problem space. Requiring students to solve design activities in the classroom that are different in surface features, but may have similar underlying operational concepts, would broaden their schema of problems that fall within the same category, and allow them to generate solutions more fluently. The ability to make inference and elaborate is a critical skill that distinguishes the expert from the novice in this study. Curriculums that integrate scientific enquiry skills in the engineering design process may be a step in the right direction to develop student's ability to infer and elaborate. According to Crismond (2007, p. 27), "Students can develop their own guidelines based on tests they conduct by formulating design rules-of-thumb." As they evaluate scientific findings in relationship to their engineering solutions, they will grow in their ability to identify and add missing details of a solution as experts are able to do.

As efforts to infuse engineering design in technology education continues, the presence of these thinking skills and cognitive strategies emphasize that they cannot be ignored in the instructional process. Clearly, more studies need to focus on the variety of thinking skills and cognitive strategies used in engineering design and the most effective instructional techniques to develop these skills and strategies.

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Performance and Cognitive Assessment in 3-D Modeling

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Abstract

The purpose of this study was to investigate identifiable differences between performance and cognitive assessment scores in a 3-D modeling unit of an engineering drafting course curriculum. The study aimed to provide further investigation of the need of skill-based assessments in engineering/technical graphics courses to potentially increase accuracy in evaluating students' factual and conceptual knowledge in preparation for the workplace. The study consisted of 92 high school students enrolled in Drafting II-Engineering. Students were administered existing assessment

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items provided in the 3-D Modeling unit of the Drafting II-Engineering curriculum. The results provided evidence that there were no significant differences between performance and cognitive assessment in the particular unit; however, it is necessary to further develop and implement performance-based assessments in Career & Technical Education that require students to exhibit both skills and knowledge.

Introduction

Over the years, state and national education organizations have set standards and used initiatives such as the No Child Left Behind Act of 2001 (2002), Carl D. Perkins Career and Technical Education Act of 2006 (2006), and the amended Elementary and Secondary Education Act of 1965 (2002) to help improve state curricula and instruction. Improvement in such areas often includes updating or introducing new curricula and utilizing standardized assessments to gauge school quality and teacher effectiveness. While these transformations in educational practice and instruction are somewhat effective, changes in assessment practices are also required (Firestone & Schorr, 2004).

The primary role assessment plays in education is to enhance student learning through classroom instruction and it is secondarily used to hold teachers and institutions accountable and stimulate educational reform (Herman & Aschbacher, 1992, NCTM, 1993, and Linn, 2000). Too frequently standardized assessments encourage a narrow, instrumental approach to learning that emphasizes the reproduction of what is presented at the expense of critical thinking, deep understanding, and independent activity (Boud, 1990). A common form of standardized assessment is curricular tests. Standardized curricular tests are generally used at the state level for school accountability and to better assess students' mastery of approved skills and knowledge. However, educational researchers have observed that most items on standardized curricular tests often require little more than students' recall of facts to arrive at a correct answer (Masters & Mislevy, 1993). Kiker (2007) notes that business and industry leaders, as well as school reform advocates, generally agree that in order for students to be successfully prepared for further education and/or the workforce requires more than traditional core academic skills. In order to gauge successful development of performance skill, assessments must accurately measure what knowledge students have learned and can demonstrate, whether academic or career oriented. Cognitive assessment may suffice for disciplines that do not fully subscribe to constructivist learning theory, but Career and Technical Education (CTE) frameworks necessitate holistic assessment means and methods that incorporate performance measures (Rojewski, 2002).

Review of Literature

Improvement of curricula and instruction often includes updating or introducing new curricula and utilizing standardized assessments to gauge school quality and teacher effectiveness. Development of assessments must measure 21st century skills and accurately represent what knowledge students have learned and can demonstrate, whether academic or career oriented (Gordan, 1998). In addition, these skills are commonly required for functioning in industry and illuminate students' learning and thinking processes (U.S. Office of Technology Assessment, 1992).

Due to their specialized nature, skills found in engineering/technical graphics and other courses in CTE may require multiple types of assessment. However, the current school accountability measurement system leans heavily in favor of using only standardized cognitive assessment. Educational practitioners discuss performance assessment as being a worthy alternative assessment to be utilized in conjunction with existing standardized cognitive assessments (Flexer & Gerstner, 1993). However, further research is needed in the field to identify how performance assessment can be utilized as a viable form of assessment in engineering/technical graphics courses.

Cognitive assessments generally come in the form of objective paper and pencil classroom test items and standardized tests used for external assessment. Traditional objective classroom assessments are frequently summative and are used for final exams and other forms that require the teacher to assign a grade (Cross & Angelo, 1988). According to Linn (1993) these types of assessments focus on basic skills and practice of factual knowledge. However, multiple choice objectivity types of tests are convenient for teachers because they can be automatically scored, and their markings are assured of having no form of bias (Baker, 1997).

A standardized test is generally defined as any test that is administered, scored, and interpreted in a consistent, predetermined manner. Popham (2002) indicates that standardized assessments can be found in two forms, national achievement tests and standardized curricular tests. National achievement tests are standardized assessments that are commonly designed to determine how a test taker will perform in a subsequent setting. In 2001 there were five nationally standardized achievement tests, such as the Iowa Tests of Basic Skills, that were used in the United States public schools (Popham, 2002). Popham (2002) states that there is a high likelihood that the specific content included in this and similar tests may be seriously inconsistent with local curricular aspirations. Many education policy makers assume that national achievement test content will mesh well with what is supposed to be taught locally, but test takers must cope with considerable national curricular diversity. A study at Michigan State University conducted almost two decades ago suggests that as many as 50 percent of the items included in a nationally standardized achievement test may cover content that is not taught in a given locality (Popham, 2002).

Standardized curricular tests are widely used types of cognitive assessment and are generally used at the state level for school accountability and to better assess students' mastery of approved skills and knowledge. According to Boud (1990), in many cases these tests encourage a narrow, instrumental approach to learning that emphasizes the reproduction of what is presented at the expense of critical thinking, deep understanding, and independent activity. As a result, schools and teachers tend to narrow their curricula and courses with the aim of helping students pass tests from external agencies (Baker, 1997). In a study conducted by Tan (1992), he concludes that frequent usage of formal standardized curricular testing causes negative effects on our education system even with tests well linked to instruction. Many argue that alternative types of assessment should be used. If alternative assessments are implemented properly, motivation and learning progress will increase and school instruction can be correctly evaluated for effectiveness (Dochy & McDowell, 1997).

Administrators and educational researchers are becoming increasingly interested in alternative assessment. There is no single definition of alternative assessment, but it has been described as an alternative to standardized testing and all of the problems found with such testing (Huerta-Macías 1995). Garcia and Pearson (1994) include the following in their review of these labels: performance assessment, portfolio assessment, informal assessment, situated (or contextualized) assessment, and assessment by exhibition. They state that alternative assessment consists of all efforts that do not adhere to the criteria of standardization, efficiency, cost effectiveness, objectivity and machine scoring. Most importantly this type of assessment provides alternatives to traditional testing in that it reviews regular classroom activities, reflects the curriculum that is actually being implemented in the classroom, provides information on the strength and weaknesses of each student, provides multiple pathways to gauge student progress, and is more multi-culturally sensitive and free of norm, linguistic, and cultural biases found in traditional testing (Garcia & Pearson, 1994).

Many researchers inquire if alternative assessments can be aligned to many of the states' general or functional curricula. Browder and Flowers (2004) conducted a study in three states where experts in mathematics and language arts, along with a group of stakeholders (teachers and administrators), examined the performance indicators relative to their alignment to national standards and curricula. On the surveys, 86 percent of math experts and 70 percent of stakeholders indicated that performance indicators were clearly linked to national math standards. Eighty-six percent of language arts experts and 100 percent of stakeholders that responded to the survey indicated that performance indicators were clearly aligned to language arts standards. The results suggest that alternative assessments have a strong focus on academic and functional skills.

A widely used form of alternative assessment is performance assessment. Performance assessment is defined as "testing methods that require students to create an answer or product that demonstrates their knowledge or skills" (U.S. Office of Technology Assessment, 1992). According to Elliot (1997) performance assessments are best understood as a continuum of assessment formats that range from the simplest student constructed responses to comprehensive demonstrations of work over time.

Performance assessment of students' achievement is not new to many educators but is usually only apparent in the areas of physical education, art, music, and vocational and technological arts. To a large extent, students' products or performances are used to determine whether learning objectives of a class have been met (Elliot, 1997). However, performance assessment is becoming more prevalent in core classes such as mathematics, science, language arts, and social studies. In a study conducted by Flexor and Gerstner (1993), issues involving the construction of alternative forms of assessment by mathematics teachers were studied through the case study of assessment development in three elementary schools. Three schools with 14 third-grade teachers were selected and matched with three comparison schools where data would also be collected. The three schools continued to use the end-of-chapter tests, but they supplemented those with other assessments that involved more conceptual understanding and higher order thinking. It was concluded that even though there were dilemmas among teachers, positive effects were observed in their students using performance assessment.

Research Question

The research question examined in this study was: Is there an identifiable difference between performance assessment scores and cognitive assessment scores in the 3-D Modeling unit of a state Drafting II-Engineering curriculum? To further investigate that question, the following research hypotheses were proposed:

1. There is no significant difference in means of the student participants' performance and cognitive assessment scores in the 3-D modeling unit.

2. There are no significant differences in means of the student participants' performance and cognitive assessment scores in the 3-D modeling unit among grade levels.

To evaluate the first hypothesis, a paired samples T-test was used to determine if differences existed between the means of the assessments. The second hypothesis was evaluated through an analysis of variance procedure used to determine differences in the means of the assessments among grade levels.

Participants

The participants in this study were enrolled in the Drafting II-Engineering course of study in a North Carolina public school. Drafting II-Engineering introduces students to the use of the graphic tools necessary to communicate, analyze, and understand the ideas and concepts found in the areas of engineering, science, and mathematics. Topics include teaming and communication skills, 3D modeling, manufacturing processes, dimensioning and conventional tolerancing, sectional views, auxiliary views, and pattern development. This course is demanding, requiring the application of complex visualization and computer skills. These skills are used to assess, communicate, and design virtual and physical models used in science, mathematics, manufacturing, transportation, and structural systems (North Carolina Department of Public Instruction, 2005). The principles learned were applied using a constraint-based modeling program provided by the local education agency.

The Drafting II-Engineering classes in this research were taught in the spring semester of 2009. Student participant demographic data was collected and summarized in Table 1.

Table 1.
Demographics of Participants

Category	Frequency	Percent
Gender		
Female	8	8.7
Male	84	91.3
Class		
Freshman	3	3.2
Sophomore	22	23.9
Junior	41	44.6
Senior	26	28.3

The make-up of the participants in this study enrolled in Drafting II-Engineering during the spring semester of 2009 was 8 females and 84 males. These students ranged from 14-19 years old and included 3 freshman, 22 sophomores, 41 juniors, and 26 seniors. There were approximately ten times as many males as females participating in the study. A very low percentage of participants were classified as freshmen, likely due to the enrollment restriction of Drafting II-Engineering until completion of the pre-requisite Engineering/Technical Graphics I course. A high percentage of participants was classified as juniors and seniors primarily due to engineering/technical graphics instructors suggesting that students complete a geometry course that is traditionally a sophomore level math prior to enrolling in Drafting II-Engineering.

Data Collection

A research proposal was submitted to the Institutional Review Board in order to gain approval for the study. Next, the study topic was discussed with local education agency professionals and permission of involvement in the research study was granted. During the traditional school year, high school level career and technical education teachers in the local education agency meet quarterly with their respective professional learning communities. This venue was utilized to discuss the topic of the study and spur interest among the drafting/aerospace instructors. After gaining IRB approval a survey was handed out to all Drafting II-Engineering course instructors. The survey inquired about the instructors' participation interest in serving as test administrators and the approximate student enrollment for the spring semester. All Drafting II-Engineering course instructors volunteered to participate in the study and serve as test administrators for the 92 student participants. Following the meeting, an email was sent to the surveyed instructors to provide further details about the study and to finalize the list of participating instructors.

During the next drafting/aerospace meeting the test materials were provided to the instructors and explained in detail to ensure an efficient process. The test materials included the following items: 1) instructions numerically outlining test administration procedures, 2) the cognitive assessment including 68 multiple choice items, 3) scanning sheets for students to input their respective answers, 4) the performance assessment including a prescribed 3D-model problem, and 5) a USB flash drive to transport performance assessment data.

This study used existing assessments that all students enrolled in Drafting II-Engineering in North Carolina Public Schools would be administered regardless of the presence of this study. However, the testing materials provided to the participating instructors helped ensure proper consistency regarding teacher instruction and test administration. The performance and cognitive assessments were administered following the completion of the 3-D Modeling unit in the Drafting II-Engineering course curriculum. To ensure that test administration was consistent with all instructors, the following test procedures were strongly suggested: 1) Allow no more than 120 minutes for assessments to be completed, 2) Provide a computer with the district provided constraint-based modeling software to each student, 3) Administer the cognitive assessment and scan sheets foremost, 4) Administer the performance assessment individually following students' completion of the cognitive assessment, 5) Collect all performance assessment data using the provided USB flash drive, 6) Place the USB flash drive with performance assessment data and scanning sheets with cognitive assessment data into a provided manila envelope and mail back to researchers.

During the course of the semester, the instructors administered the assessments to the student participants at the culmination of the 3-D Modeling unit of the North Carolina Drafting II-Engineering curriculum. Upon the participating instructors' test administration completion, the testing materials were returned to the researcher and the cognitive and performance data were compiled. A common scanner scored the cognitive assessments, and the scores were calculated by state-provided course management system software. The performance assessment data were transferred to a North Carolina State University (NCSU) professor to be evaluated using the state-provided rubric.

Instrumentation

Since the main subject matter for this study is investigating identifiable differences between cognitive and performance assessments in the North Carolina state high school Drafting II-Engineering curriculum, the state-provided assessments included within the curriculum were used. All CTE assessments were provided by the North Carolina Department of Public Instruction in the course management system classroom test bank. All North Carolina Department of Public Instruction cognitive items are aligned with the standard course of study and have undergone reliability assessment and content validity checks (North Carolina Department of Public Instruction, 2005).

The cognitive assessment was composed of 68 multiple choice test items that were provided in the course management system classroom test bank. These align with the objectives set forth for the 3-D modeling unit of the Drafting II-Engineering standard course of study by the North Carolina Department of Public Instruction. A scanning sheet accompanies the cognitive assessment for more efficient scoring purposes. The scanning sheet is aligned with the correct answers within the course management system test bank; therefore, student scores were assigned accurately.

The performance assessment was composed of a 3D-model and was also provided by the course management system test bank. This assessment challenged students to actively demonstrate their understanding of 3-D modeling techniques. The test item was given in the form of a multi-view drawing and required students to construct a 3D-model using the provided constraint based modeling software. The test item was chosen because it is aligned with the objectives set forth for the 3-D modeling unit of the Drafting II-Engineering standard course of study by the North Carolina

Department of Public Instruction and is part of the curriculum. A standard rubric is provided in the Drafting II-Engineering curriculum to evaluate the 3D-model prescribed. Similar to the cognitive assessment, the rubric provided was aligned with the correct answer within the course management system test bank; therefore, student scores were assigned accurately.

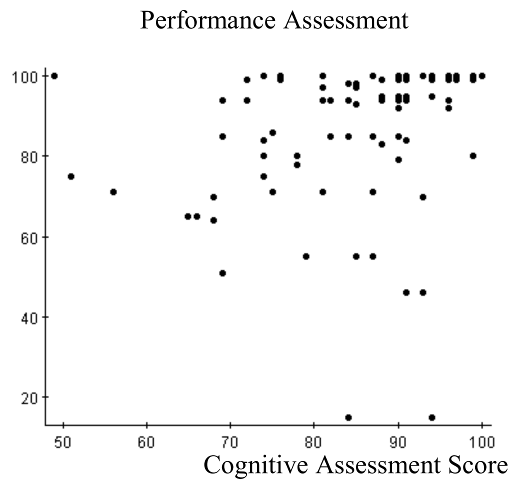
Data Analysis

Data were collected using cognitive and performance testing instruments provided by the North Carolina Department of Public Instruction and utilized through their course management software. Hypothesis 1 was analyzed using a paired sample T-test for a difference in means in the student participants' performance and cognitive assessment scores in the 3-D modeling unit of the Drafting II-Engineering curriculum. Hypothesis 2 was analyzed using a One-Way Analysis of Variance (ANOVA) procedure to analyze data and investigate the differences in means in the student participants' performance and cognitive assessment scores in the 3-D modeling unit of the Drafting II-Engineering curriculum among freshman, sophomore, junior, and senior grade levels.

Discussion and Findings

The 3-D Modeling unit of Drafting II-Engineering performance and cognitive data was investigated to find identifiable differences in the means. A scatter plot (Figure 1) of cognitive assessment scores and performance assessment scores was constructed to provide a visual representation of the array of student achievement for the 92 Drafting II-Engineering student participants.

Figure 1
Scatter Plot of Scores



The scatter plot of the data does not display a clear linear alignment but does reveal clusters of scores and some outliers. The clusters demonstrate that many students scored well on the performance assessment but did not exhibit clear relationships between the assessments. However, the scatter plot does reveal some unusual outliers. Table 2 provides summary statistics of the cognitive and performance assessment scores.

Table 2
Summary Statistics

Column	Cognitive	Performance
N	92	92
Mean	84.565216	84.934784
Variance	115.76493	422.43527
Std. Deviation	10.759411	20.55323
Std. Error	1.1217462	2.1428223
Median	87.5	94
Range	51	85
Min	49	15
Max	100	100

The average of the cognitive assessment scores (84.57 of a possible 100) for the 92 engineering/technical graphics student participants were noticeably similar to the performance assessment scores (84.93 of a possible 100). The variance (115.76) and standard deviation (10.76) of the cognitive assessment scores is small in comparison to the variance (422.44) and standard deviation (20.56) of performance assessment scores indicating a larger spread of the engineering/technical graphics student participation scores on the performance assessment. The standard error (1.12) of the cognitive assessment scores is much less than the standard error (2.14) of the performance assessment scores uncovering a larger variation in score values from participant to participant for the performance assessment. The median and means of the cognitive assessment exhibit minimal deviance suggesting a rather symmetrical score distribution for this assessment. However, the median for the performance assessment is much higher than the mean suggesting that there are a larger number of high scores for the performance assessment than the cognitive assessment. The range is calculated based on the minimum and maximum scores on the cognitive assessment and performance assessment. The minimum score (15) on the performance assessment is much lower than the minimum score (49) of the cognitive assessment reiterating the unusual outliers. The lower range (51) on the cognitive assessment in relation to the performance assessment (85) supports the degree of difference in the variability of engineering/technical graphics student participants between the two assessments (refer to Figure 2).

Figure 2 and Figure 3 represent the rate of occurrence for cognitive scores and performance scores for engineering/technical graphics student participants.

Figure 2
Cognitive Histogram

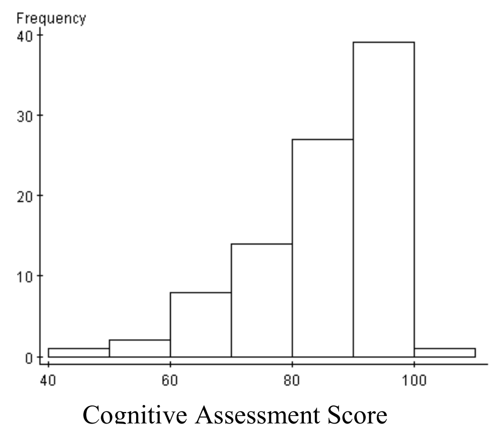
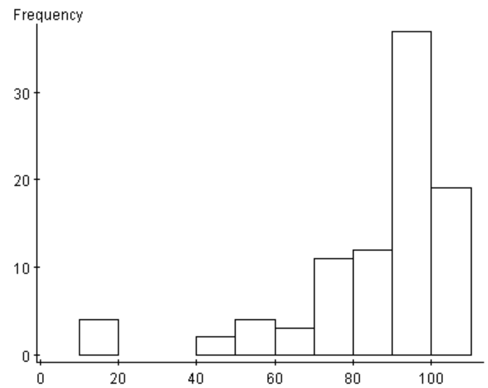


Figure 3
Performance Histogram



Performance Assessment Score

Both histograms are skewed to the left indicating an upper limit, in this case a maximum score of 100. A histogram representing a distribution is skewed if one of its tails is extended for the lowest or highest values. This non-symmetric distribution is positively skewed if the histogram has a distinguishable tail in the positive direction and negatively skewed in the negative direction (Agresti & Finlay, 1997). Negative skewness is common in education where students are evaluated after a progression of learning exercises. The performance histogram exhibits a greater skew than the cognitive histogram due to the four engineering/technical graphics student participants' scores of 15 out of 100. A hypothesis test was conducted given the clear similarities in the means with clear differences in the standard deviations of the engineering/technical graphics participant cognitive and performance assessments indicated. A paired samples T-test was used to evaluate hypothesis one: There is no significant difference in means of the student participants' performance and cognitive assessment scores in the 3-D modeling unit. Table 3 summarizes the results of the analysis.

Table 3
Hypothesis Test Results

Difference	Sample Diff.	Std. Err.	DF	T-Stat	P-value
Cognitive - Performance	0.37	2.24	91	0.17	0.87

Based on the analysis of the T-statistic (-0.17) and the proportional value (0.87), Hypothesis One failed to be rejected, providing evidence that there is no significant difference in the means of the student participants' performance and cognitive assessment scores in the 3-D modeling unit.

Dot Plots (see Figures 4, 5, and 6) of the cognitive assessment scores, performance assessment scores, and difference in assessment scores were constructed to provide a visual representation of the array of student achievement for the 92 engineering/technical graphics student participants divided by freshman, sophomore, junior, and senior grade level status. Figures 4, 5, and 6 reiterate that there are more student participants with junior and senior grade status. Figure 4 displays the cognitive assessment scores divided by grade level status and exhibit similarities in concentrated grouping around the 90 percentile reiterating the negative skewness in Figure 2.

Figure 4
VoCATS Dotplot

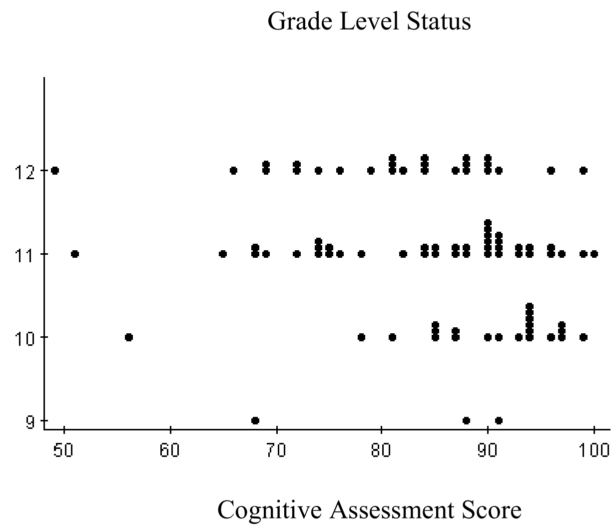
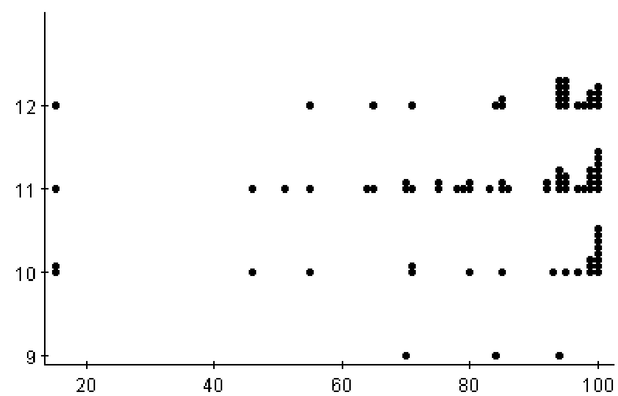


Figure 5 displays the performance assessment scores divided by grade level status and exhibit similarities in concentrated grouping in the upper 90 percentile reiterating negative skewness in Figure 3.

Figure 5
Performance Dotplot

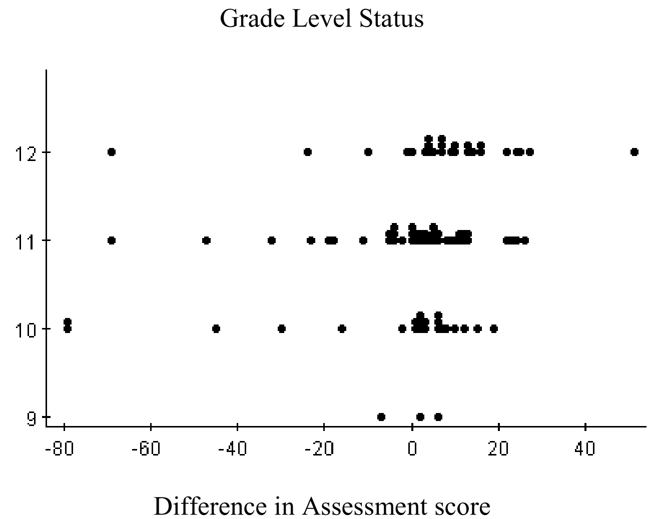
Grade Level Status



Performance Assessment Score

Figure 6 displays differences in performance and cognitive assessment scores divided by grade level status and exhibits similarities in concentrated grouping near zero providing some visual evidence that there is little or no difference between the scores of the performance and cognitive assessments among grade levels.

Figure 6
Difference Dotplot



An additional hypothesis test was conducted based on the differences in the means of Drafting II-Engineering participant performance and cognitive assessment scores among freshman, sophomore, junior, and senior grade levels. A One-Way Analysis of Variance (ANOVA) procedure was used to calculate the F-statistic to evaluate the second hypothesis: There are no significant differences in means of the student participants' performance and cognitive assessment scores in the 3-D modeling unit among grade levels.

To assist in explanation, Tables 4, 5, and 6 are utilized to investigate identifiable differences in means of cognitive assessment scores, performance assessment scores, and difference of assessment scores among grade levels. Table 4 investigates identifiable differences in the means of the cognitive assessment scores among grade levels. Although the mean of sophomore participant scores (89.45) is significantly higher than the means of freshman, junior, and senior grade level participants, the proportional value (0.06) is greater than the established critical value (.05) providing evidence that there are no significant differences in the means of the cognitive assessment among grade levels.

Table 4
Analysis of Variance Results

Factor Means

Grade	n	Mean	Std. Error
Freshman	3	82.333336	7.2188025
Sophomores	22	89.454544	1.9942855
Juniors	41	84.268295	1.6853112
Seniors	26	81.15385	2.1047144

ANOVA Table

Source	F-Stat	P-value
Treatments	2.5648289	0.0597

Table 5 investigates identifiable differences in the means of the performance assessment scores among grade levels. Although the mean of senior participant scores (88.35) is significantly higher than the means of freshman, sophomore, and junior grade level participants, the proportional value (0.79) is greater than the established critical value (.05) providing evidence that there are no significant differences in the means of the performance assessment among grade levels.

Table 5
Analysis of Variance Results (Performance)

Factor Means

Grade	n	Mean	Std. Error
Freshman	3	82.666664	6.960204
Sophomores	22	82.72727	5.739731
Juniors	41	84.12195	2.886722
Seniors	26	88.34615	3.6819487

ANOVA Table

Source	F-Stat	P-value
Treatments	0.3492449	0.7898

Table 6 investigates identifiable differences in the means of the differences of assessment scores among grade levels. Based on the analysis of the F-statistic (1.73) and proportional value (0.17), we fail to reject the second hypothesis providing evidence that there are no differences between the means of the Drafting II-Engineering student participants' performance assessment scores and cognitive assessment scores among grade levels.

Table 6
Analysis of Variance results (Differences)

Factor Means

Grade	n	Mean	Std. Error
Freshman	3	0.33333334	3.8441875
Sophomores	22	-6.7272725	5.839551
Juniors	41	-0.14634146	2.8153675
Seniors	26	7.1923075	4.0504584

ANOVA Table

Source	F-Stat	P-value
Treatments	1.729463	0.1668

The researchers chose not to investigate identifiable differences in means between performance assessment and cognitive assessment scores in Drafting II-Engineering between genders due to the low numbers of female participants (8) making up only 8.7 percent.

Conclusions

Based on the results of this study, the following explanations could be made. First, although each assessment construct is different, the data suggests that students' access of their content knowledge is consistent in performance and cognitive assessments in engineering/technical graphics. Second, students in freshman, sophomore, junior, and senior grade levels form skill-based knowledge in a consistent manner during instruction. Additionally, the data suggests that students in all high school grade levels access their content knowledge consistently in performance and cognitive assessments.

Performance assessment is a requirement for most skill-based courses in Career & Technical Education to properly gauge student competence and ability. This type of assessment often allows students the opportunity to learn through a more active process involving a students' construction rather than a selection of responses. Learning in this fashion can be explained with the constructivist learning theory that in turn is often connected to performance assessment. CTE teachers who embrace this learning theory typically take advantage of instructional approaches that allow them to design instruction that goes beyond rote learning to meaningful, deeper long lasting understanding. In addition to being connected to the constructivist learning theory, skill-based courses in CTE that utilize performance assessment commonly attract kinesthetic learners. Students associated with this predominant type of learning style learn by actually carrying out the physical activity and benefit from performance assessment because it caters to their strengths.

Future research like this can open the possibility of modifying assessment practice, given the need for varied assessment for individual and school accountability. More research in engineering/technical graphics and other areas in Career & Technical Education is necessary to further develop and implement performance-based assessments that require students to exhibit both skills and knowledge.

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The STEM Initiative:
Constraints and Challenges

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Abstract

There is considerable national interest in STEM initiatives, but yet there is little discussion concerning what STEM means in terms of a curriculum concept to be applied to school programming. This article focuses on STEM as a curriculum concept. First, STEM programming is discussed in terms of separate subjects, correlated and broad fields curriculum models. The issue of subject structure is examined. A distinction also is made between the four STEM subjects in terms of formal and applicative uses of knowledge. Second, some practical programming issues are discussed. These include the almost exclusive focus on science and math to the exclusion of technology and engineering; the challenge of serving multiple student populations; and the issue of what to do with the "T" in STEM. A concluding section suggests ways that the STEM initiative can be conceptualized in order to realize its considerable potential to achieve curriculum reformulation.

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Introduction

Interest in STEM (Science, Technology, Engineering and Math) instructional models is literally exploding across the educational landscape. Universities are exploring STEM models as a way to restructure science and engineering instruction; secondary schools are engaged in experimenting with modified curricula; the educational literature is full of references to STEM initiatives; and consultants and entrepreneurs are rushing into the educational market place with assurances that they too can aid in the implementation of effective STEM programming. Largely initiated and funded by the National Science Foundation, STEM initiatives are now supported by other foundations, professional organizations, universities, publishers, schools systems, and producers of educational materials among groups and individuals that see promise or profit in the possibilities of curriculum reorganization through STEM initiatives (Kuenzi, 2008).

Part of the explanation for the national frenzy over STEM programming is money. Grants from the National Science Foundation in addition to other organizations are funding program experimentation. Scores are jumping onto the money cart to get their share. STEM initiatives feed into a national concern over the relative capacity of the U.S. to compete in the international economic arena. On international tests comparing academic performance, American students do not fare very well. Greater national educational attention on science, technology, engineering and math addresses the political contention that schools must shoulder a good part of the blame for the nation's weakening ability to compete internationally (Kuenzi, 2008; National Academies, 2006; The New Commission on the Skills of the American Workforce, 2007). But also, powerful national organizations, such as the National

> Academy of Engineering and the National Academy of Science, are supporting STEM initiatives. There is mounting concern over the lack of young Americans preparing for scientific and engineering professions. (National Academy of Engineering and National Research Council, 2009; Pearson & Young, 2002).

STEM does not represent a specific curriculum model; rather, there are many ways to formulate STEM programming. In fact, it is hard to discern what exactly is meant by "STEM." Practically any kind of educational intervention that is even remotely associated with science, technology, engineering or math is referred to as a STEM innovation. This lack of a solidifying perception of STEM threatens over the long-term to destroy support for the movement. Failure to deliver results will probably exceed successes.

Above all, STEM represents a way to think about curriculum change. It is a *concept* of how to restructure what we teach and what students learn. The purpose of this paper is to first briefly unpack what is meant by STEM in terms of a curriculum concept. What STEM represents is discussed in terms of curriculum theory. Second, some issues related to instructional programming will be explored. By framing the discussion in terms of curriculum theory we can more clearly see some to the constraints and challenges faced as STEM initiatives are pursued. Curriculum theory also helps us to formulate a common framework within which to discuss STEM and its application in the school.

Unpacking STEM as a Curriculum Concept

Traditionally, the most common and widespread curriculum pattern is the separate subjects (McNeil, 1990). Each is taught separately with little attention given to the interrelationships between subjects. Secondary level students, for example, are exposed to discrete subjects to study, such as algebra, chemistry or history. An ends-means curriculum organization tends to be used, starting with pre-specified objectives, or standards, and ending with tests to assess attainment of the discrete course elements. The purpose of instruction is to efficiently transmit a predefined body of formal content thought to be essential to students. The degree to which instruction is "successful" is assessed through tests. Instruction is conceived primarily as a process of knowledge transmission.

In contrast, an implied characteristic underlying STEM is what is termed an "integrated curriculum design." This is a marked departure from the way that instruction tends to be organized and delivered in schools. Subjects such as science, technology, engineering and math are integrated in ways that show more clearly the functional relationship between each (Kuenzi, 2008; McNeil, 1990). In real-life situations, knowledge tends to be used across fields of study. The integrated curriculum design attempts to capture the interrelationships within and between subjects and thereby ground learning in the actual way that knowledge is used. Not only is leaning thought to be enhanced, but it is considered to be more relevant. The student learns how knowledge is applied (McNiel,1999; Herschbach, 2009).

The Correlated Curriculum

STEM implies an integrated curriculum design. There are two basic ways that integrated curricula are organized: correlated or broad fields. The correlated curriculum pattern tends to be the most poplar option because it retains the identity of each subject, and each may be offered as a separate course (McNeil, 1990). Concepts learned in math, for example, may be applied to physics or technology education through coordinated planning, but each subject area retains its separate identity. It is a more comfortable fit with the ongoing school instructional program because very little adaptation is required to what is already an on-going separate subjects orientation. It is a curriculum pattern that is familiar to administrators, teachers and the educational public. What is required, however, is coordination and planning among the different stand-alone subjects.

One challenge that the correlated curriculum pattern presents is, in fact, the high level of on-going coordination that is required. To be most effective, there has to be a clear relationship between what students learn in one subject with what students learn in the other associated subjects. This requires an ongoing, close working relationship on the part of the involved teachers, with regular and continuing planning and coordination. But in addition, the way that subject fields are formally and "conventionally" organized often has to be abandoned or substantially modified in order to adapt to the requirements of coordinating with the other associated subjects (McNeil, 1990). Algebra instruction, for example, may have to be reorganized and sequenced other than the way that it traditionally has been: little integrated understanding may be achieved if a concept in algebra is presented three months after it is needed in physics and is ignored in engineering.

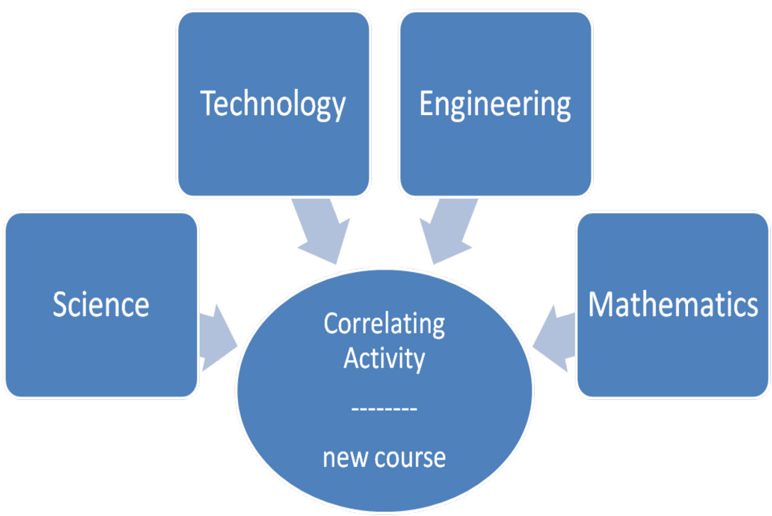
The Broad Fields Curriculum

The broad fields pattern is a second way to integrate instruction. With the broad fields curriculum, a cluster of related but different subjects is organized into a single area of study (McNeil, 1990). Language arts, graphic communications, and general science are examples. The individual subjects lose their own separate identity since the subject matter from the different fields is combined into a new instructional configuration. A general science course, for example, may include units from biology, physics, earth science, and chemistry. Integration can be done with a single course or with a sequence of related courses.

A fundamental challenge associated with the broad fields curriculum design is to formulate an effective organizing framework for instruction. When the subject matter from different fields is integrated into a new course structure, the structure inherent in the different parent fields tends to be lost. This means that a new way has to be found to organize instruction so that some of the identity of the original parent fields is retained while at the same time an integrated program design is achieved that has a clear organizing framework.

The most common way to achieve a coherent organizing framework is through activities (Figure 1). The curricular emphasis shifts from organizing instruction around the formal structure of fields of study to focusing on a sequence of activities that guide students through the integrated use of knowledge (Herschbach, 2009; National Academy of Engineering and National Research Council. 2009). A course, for example, may be organized around the construction and testing of a solar-power vehicle. All of the STEM subjects are brought together to focus on the activity, with knowledge selectively used to address the scientific, engineering and fabrication challenges inherent in designing a solar-power vehicle. Selected formal and applicative knowledge is used (Figure 2). Of course, the conditioning learning factor is the demand the activity makes of the full range of potential knowledge. It is the characteristic of the activity that conditions the extent to which knowledge is used from the different related fields of study (Mitcham & Mackey, 1972).

Figure 1: Broad Fields of Curriculum Pattern



The broad fields curriculum pattern tends to shift instructional focus away from the way that teaching and learning is organized in schools along different discrete subject fields to an activity-based curriculum with less formal identification with traditional fields of study. Formal knowledge is selectively used, but educators are required to think differently about how instruction is organized and taught. The traditional ends-means model of instruction, starting with defined objectives and cumulating in paper and pencil student testing is less appropriate. Progress through content elements tends to be integrative and uneven, not linear, because it is linked with activity. Like the correlated curriculum design, continuing planning and coordination, nevertheless, are required among teachers; but teachers also have to learn to instruct and evaluate students in different ways.

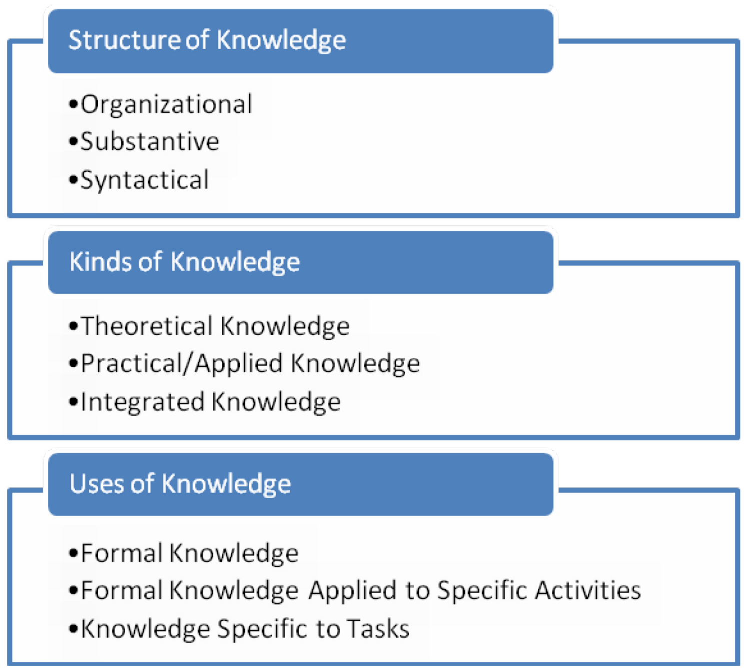
Use of the design process is one of the more common ways that broad fields programming is addressed (Herschbach, 2009; National Academy of Engineering and National Research Council, 2009). The design problem functions as a correlating channel for learning, with particular emphasis placed on the integration of science and math with technology and engineering (Banks, 1994; Kolodner, 2002; Sanders, 2008; Raizen, et al., 1995; Wicklein, 2006). Students bring what knowledge they know to bear on the design problem, and what they do not know they research. Knowledge is used as a tool to solve problems. At the same time, however, there is room for well-defined, selected stand-alone units of instruction that address the acquisition of formal knowledge.

Subject Structure

As previously suggested, in the case of both the correlated and broad fields patterns, the need to coordinate the sequencing of subjects presents a formidable challenge. It is, ultimately, the formal structure of a given subject that defines its characteristics and sets it off from other subjects. As Bruner (1961) reminds us, helping students to identify and understand the underlying formal "structure" of various fields of study is essential to learning. The focus is on higher-level conceptual learning which gives coherence to what sometimes can be fragmented and loosely organized "bits and pieces" of knowledge. The structure contains crucial concepts that provide order, cohesion and significance to the subject. Bruner (1961) contends “the curriculum of a subject should be determined by the most fundamental understanding that can be achieved of the underlying principles that give structure to that subject” (p. 18).

The formal structure of a field of study can be defined in three ways (McNeil,1990;1999). One is the organizational structure (Figure 2). This is the way that one subject differs from others and defines the borders and divisions within the subject. The formal structure is what most people are familiar with. At a subtler level are a substantive and a syntactical structure. Substantive structure relates to the kinds of questions framed, the theories applied, and the data used in the course of intellectual inquiry. Syntactical structure relates to the intellectual devices used with subject fields to collect data, test assertions, and generalize findings.

Figure 2: Organization of Knowledge



Because structural characteristics are most clearly embedded in specific formal, stand-alone subject areas, instructional stress tends to be placed on a separate subjects organizing pattern in schools (McNeil, 1990; Newman, 1994). This is one reason why the separate subject pattern is so widely used for organizing instruction. The formal structure is clear in geometry, physics and chemistry, for example, but considerably less so in technology education, general science or cultural studies. It is more difficult to retain and convey the structural characteristics of a field of study through an integrated curriculum design. Sequencing is a challenge, but also integrated curriculum patterns tend to make selective use of instructional elements within fields of study; instructional identity tends to get lost.

Formal and Applied Knowledge

Another way to think about the formal structure of fields of study is the difference between formal and applied knowledge (Figure 2) that influences how subject matter is selected and sequenced. In fields such as math, physics, and chemistry, as suggested, students tend to engage in learning the formal structure. These are the concepts, laws, theorems and intellectual devices that make up the substantive and syntactical structure of the specific field. They underlie the field and make it distinct. There often is little concern about how formal knowledge is applied, however. In contrast, in fields such as engineering and technology, formal knowledge is used selectively to address specific problems, so only a partial understanding of the formal subject is achieved (Herschbach, 1996). It is applied knowledge, specific and limited knowledge that is needed to only address the current problem at hand. Some concepts in chemistry, for example, simply may not be covered in engineering and math and biology may be overlooked entirely.

Unfortunately, applied knowledge may be considered of lower importance because it relies on only a partial understanding of formal learning. Engaging students in the learning of formal and applied knowledge across four integrated instructional areas, such as in STEM, is a challenge.

Uses of Knowledge

The challenge of addressing the differences between formal and applied knowledge becomes apparent when considering how knowledge is applied to work. The broad fields curriculum pattern is most widely used with technical instruction because it closely mirrors the way that knowledge is selected and applied by practitioners. Engineers, technicians of all sorts, skilled craft workers and a host of other individuals basically use three kinds of knowledge: selected elements of formal knowledge, formal knowledge as it is applied to the specific task, and knowledge specific to the task (Figure 2).

Many work tasks draw from formal knowledge. For example, specific scientific procedures or mathematical concepts may be an integral component of the job task. Selected knowledge basically is applied unaltered in its formal form.

Work tasks also make selective use of formal knowledge applied in conjunction with specific technical knowledge. Knowledge of geometry is needed, for example, to calculate rafter and stud angles on a roof dormer. A combined knowledge of both roof design and geometry is required. The builder needs to learn the selective use of geometry, but does not have to have a complete understanding of the subject field of geometry as it is formally organized.

But there are also some tasks that are purely technical and relate solely to the technical procedure. They are specific to the technical field and do not make use of the formal knowledge of other subjects.

As previously observed, because of the way that the broad fields curriculum pattern selects and makes use of the three forms of knowledge, it is less useful for conveying an understanding of the formal structure of fields such as calculus, physics, chemistry, or biology, among others. On the other hand, the broad fields pattern is a very effective way to organize engineering and technology instruction because they are interdisciplinary and applicative subjects (the T and E in STEM). Instruction tends to be built around the integrated use of knowledge selectively drawn from formal fields. Instruction is organized according how knowledge is used (McNeil, 1990).

But again, this pattern is less useful for the purpose of organizing formal subjects such as science and math because of the difficulty in adequately conveying an understanding of the formal structure of the fields. This disjunction between the two ways that knowledge is organized and used creates complex organizing and programming challenges.

The Character and Validity of Knowledge

As suggested in the above discussion, differences between interdisciplinary, integrative subjects, such as engineering and technology, and formal academic subject fields such as physics and algebra, are a major curriculum stumbling block with STEM initiatives that yet is to be resolved. These issues can be further examined by focusing on fundamental epistemological characteristics that tend to be glossed over, that is, issues relating to the character and validity of knowledge.

"Science" is a broad descriptive term that acquires specificity only when it defines a particular field of study, such as physics, or better still, molecular physics. The *function of science is to discover and advance knowledge*. To this end, science makes use of the scientific tools of investigation, and relies heavily on *mathematics as an analytical tool*. Specific fields of study tend to be taught formally as stand-alone subjects. As formal fields of study, science and mathematics have a close symbiotic relationship. Instruction in both fields also tends to convey a broad and deep understanding of the organizational, substantive and syntactical structures of the fields. Indeed, as previously stressed, a structural understanding is essential to learning (Bruner, 1960; Herschbach, 1995; McNeil, 1999).

The term "technology" is even broader than "science," and refers to just about everything in the designed, man-made world. There is no practical way to convey meaningful technology instruction without tying it to specific activity. *Technology is manifested through abstract and concrete artifacts* (Feenberg, 2002; Dasgupta, 1996; Pacey, 1999; Skolimowski, 1966). When technology is defined in terms of a specific application, such as micro precision instrumentation, instruction is integrative and interdisciplinary in scope. And *it is the bond with application that distinguishes technological knowledge from set bodies of formal knowledge* (Figure 2.) Technological applications make use of formal knowledge, but in very specific ways. The inherent interdisciplinary activity makes technology a good candidate for an integrative framework around which STEM subjects can be organized except that only selective use is made of formal knowledge.

"Engineering" differs from the other three subject areas in that it primarily refers to *preparation for specific occupations* (Oaks, Leone & Gunn, 2001). It is in one sense a vocational subject at the collegiate level. The requirements of the specific occupational field define the instructional content. Engineering, then, like technology, *selectively makes use of formal knowledge from science, mathematics and technology*. The specific selection and use of knowledge, however, depends on the occupational field of engineering understudy.

Of the four STEM areas, "math" is the most clearly defined as a formal subject. It already has wide recognition in schools, and instruction tends to be organized around students learning its formal organizational, substantive, and syntactical structures. *Other STEM subjects tend to supply a supporting* *role* in that they demonstrate how math concepts can be applied with the expectation that better math learning will result. The broad fields curriculum pattern, as previously observed, has limited use since only selected mathematical concepts are applied in a very restricted way to address the particular activities. As suggested, the correlated curriculum design often lacks full integration.

The four STEM fields, in sum, have epistemological characteristics that differ markedly. These characteristics must be fully recognized and accommodated in programming in order to preserve the intellectual integrity of each field. Otherwise a very limited understanding results that undervalues specific intellectual contributions or ignores the collective value of each.

Some Issues Related to Programming

In addition to issues relating to the substance and structure of knowledge STEM as a curriculum concept presents a number of practical programming issues. To be sure, integrated curriculum designs are not new. They emerged during the 1920s as part of the progressive school era (Kilebard, 1987). At the time it was recognized that the intellectual integrity of the various integrated subject fields was in part lost through integration. But educators were primarily concerned with making school instruction more relevant to the life experiences of students. Today, there is an educational environment that is strongly focused on a separate subjects orientation, "academic" achievement, testing, and an emphasis on the "basics." There is considerably less concern about making instruction more relevant to life. It is difficult so see how integrated STEM programming with such applicative subjects such as technology and engineering fit into current school programming. The tensions between current subject-matter divisions and the integrative programming implied by STEM create a number of programming issues that yet are to be resolved.

The Illusion of STEM Programming

One major issue is the limited perception of what STEM represents. STEM is widely perceived as **related** mainly to strengthening math and science education (National Commission on Mathematics and Science, 2000). As one recent national report observes, “Despite all of the concerns by policy makers, educators, and people in industry about the quality of U.S. K-12 STEM education, the role of technology education and engineering education have hardly been mentioned. In fact, the STEM acronym has become shorthand for science and mathematics education only, and even these subjects typically are treated as separate entities” (National Academy of Engineering and National Research Council, 2009, p. 150). “Technology,” along with applications to engineering is assumed to automatically fall under math and science. Much of the national attention STEM has attained is because of its potential impact on math and science education, with little interest in “retooling” the subject fields in order to share instructional space with technology and engineering (Kuenzi, 2008; Moyer-Packenham, et. al, 2008; National Commission on Mathematics and Science Teaching for the 21st Century (2007).

But even with the focus on math and science, there is little evidence that the programming implications of STEM are realized. One of the most widespread, but highly limited approaches to STEM programming is to retain the traditional subject matter distinctions in school and to imagine that integrated learning is actually happening. When there is an increase in math students, for example, it is assumed that there is an increase in “STEM” students; but yet, it may be hard to find ways that math instruction has been changed. This is largely an exercise in labeling. A benefit may be that greater attention is directed toward math and science, but it is a highly restricted vision of STEM programming..

A great deal of STEM programming in schools today appears to be in the form of units of study interjected into slightly modified, conventional stand-alone courses. Commercial modules and STEM worksheets abound in the market place, yet they often represent little in the form of substantial change. While there are notable exceptions, what is often referred to as STEM courses requires little in the way to creative, integrated programming. STEM implementation tends to be an illusion.

What is the Target Population for STEM Programming?

Connected to a limited perception of what STEM programming implies are issues related to the student populations to be served. Secondary schools tend to program subjects according to potential achievement levels. Students tend to be scheduled based on an assessment of how well they can perform at a given level (Newman, 1994).

In many schools, the STEM initiative tends to be perceived mainly as a way to strengthen stand-alone math and science courses for college-bound students, with less attention give to “lower” programming levels. STEM is viewed as applying primarily to “college caliber” students. It is anticipated that emphasis on STEM (primarily on the S and M) will result in more students enrolling in college preparatory course work at higher performance levels (National Academies, 2006). There appears to considerable less national interest, however, in programming designed to serve the large student population that does not elect to go to a four-year postsecondary institution of any kind (Cech, 2009; Kuenzi, 2008).

Approximately 50% of a given student cohort, does not elect to pursue additional education beyond high school, not to count the students who drop out before completion. National discussion concerning the diverse range of student populations that can profit from variations of STEM programming is limited, but yet thinking about STEM has to be broadened to include more than college-bound students if schools are to serve the great number of electricians, warehouse workers, agricultural specialists and craftsmen and technicians of all kinds that also have to be equipped to participate in our scientific and technologically orientated society. There are multiple target populations that can and need to be served (Cech, 2009; The Workforce Alliance, n.d.).

Even in the case of more college-orientated programming, there is some question about the extent to which integrated STEM courses of any kind eventually will be accepted for college admission purposes. College's admission officers continue to think in terms of a separate subjects orientation that is emulated by secondary schools in the preparation of students for entrance examinations. Colleges accept credits for APT courses, but have a lesser understanding of and a greater reluctance to give credit to integrated offerings that engage students in the applied uses of science and math. There are APT examinations in physics and algebra, for example, but none for design, technology and engineering classes. Admission officials understand what chemistry is, but they are not sure what technology education means and they are prone not to accept what appear to be "vocational" subjects. It will be difficult to realize the true potential of STEM programming until what constitutes preparation for college entrance is conceived differently.

What to do with the "T" in STEM?

Given the "conventional" way that knowledge continues to be perceived and organized for instruction, one potentially contentious, emerging issue is where will the "T" in STEM be taught. Some science educators think that they teach about technology since much what goes for "science" teaching today is actually applied technology. Practical applications of scientific concepts are used to enhance science learning.

A case also can be made for technology to be taught through engineering (National Academy of Engineering and National Research Council, 2009; Sanders, 2008). Much of engineering consists of science and math applied in the service of technological improvement and advancement. Engineering is largely an applied field with its practitioners seeking solutions to "real" technological problems. But if engineering is to be used as an integrative, correlating center of instruction, which particular field of engineering will be used and why? Civil engineering, mechanical, industrial, sanitation, hog production, aeronautics, among a host of others? There is no easy way to make this decision in school programs serving general instructional purposes for students not yet ready to make a specific, perhaps narrow career choice. At the same time, claims that "general engineering processes are taught" are difficult to sustain unless programming is designed to achieve such an objective. With few exceptions, this objective has not been met (Kelley, Brenner & Piper, 2010).

On the other hand, engineering is an ideal place to demonstrate the interdependent relationship between science, technology, and math. Engineering uses science, technology and math to make things. However, public schools tend not to offer engineering as a subject. The occupational field is relatively small, particularly when broken down into specialties. When STEM is too closely defined as preengineering education, it faces the possibility of unduly limiting the number of students that are attracted to the subject. Its appeal may be to a relatively small, select group of students. Roughly, only 5 to 6% of high school graduates enroll nationally as college engineering majors (Deloatch, 2010).

The vocational, technical and technology fields of study also make claim to the "T" in STEM. They have traditionally been applicative subjects deeply immersed in uses of technology. The distinction with engineering applications of technology is primarily one of level and objectives of instruction. Engineering tends to incorporate greater use of science and mathematics at a theoretical level, and the field tends to be more focused on the design rather than on the construction and use of artifacts (Hill, 2004; McAlister, 2004). In fields such as vocational and technical education, nevertheless, heavy use is made of technology, and considerable integrative instruction is used because technology itself is integrative.

Technology teacher educators in particular see STEM as a means of achieving greater instructional focus in schools. McAlister (2004), however, in a study of 44 teacher education programs across the country found that few aspiring teachers had the skills needed to effectively address the science, math and engineering elements of STEM. Without a substantial refocusing of technology teacher preparation programs, it is difficult to see how technology education can effectively interface at the school level with engineering content and with science and math.

Finally, as previously suggested, STEM is widely perceived as related mainly to strengthening math and science education. However, this limits its promise as a reforming concept. "Technology" is assumed to automatically fall under math and science along with applications to engineering. This reduces the potential impact of STEM. The value of using science and math to address "real world problems" is lost in the context in which knowledge is used. It is difficult to adequately address the theoretical, practical (applicative) and integrated uses of knowledge in stand-alone courses organized around the formal structure of math and science courses.

Looking Ahead

A yet unfulfilled promise of STEM is to reconceptualize how knowledge is conceived, organized and taught in schools. Within the scientific and engineering communities today there appears to be a rethinking of how knowledge is generated and used. Some of the most striking advancements are made through the combined use of knowledge spanning across traditionally different intellectual fields. More traditional subject fields are being enriched and expanded through the integration of knowledge from other formerly stand-alone subjects to form new combinations of intellectually integrated knowledge that feeds investigation, discovery and understanding. Biology, for example is crossed with physics and engineering; solar heating research is melded with building material research and new construction technology.

More so than in the 1920s, there is a greater understanding today that new forms of abstract and applied knowledge are highly productive and, perhaps, the key to addressing what are some of the most crucial problems facing humankind. There is a considerable rethinking of the way that abstract knowledge is combined, learned and used. The opportunity, however, is not fully recognized to integrate programming through STEM and to tap into the potential to organize, learn and use knowledge in highly productive ways that were formally limited by encasing teaching and learning in "traditional" stand-alone, clearly defined subjects. To more fully realize the promise of STEM programming means to move away from the conventional separate subjects curriculum design pattern. This requires substantial curriculum reformulation.

How can a STEM initiative that is representative of the integrated curriculum design pattern be functionally integrated? At least three conditions must be addressed: a) an integrated curriculum design brings together the subject matter from different fields of study in order to make clear the underlying interrelationships; b) students are exposed to the formal structure of the fields of study through learning experiences that incorporate the organizational, substantive and syntactical structures underlying the use of knowledge; and c) students engage with learning experiences that use formal, specialized and applicative knowledge.

Today, part of the interest in STEM initiatives is the perception that instruction will become more relevant to students. It is alleged that there is a crisis in education because U.S. students lag far behind in international measures of educational progress. STEM initiatives allegedly will help markedly improve student achievement, particularly in math and science. An additional hoped for outcome is that greater student interest in math, science and engineering will result from grounding instruction in ways that use knowledge. Students more readily see in their studies the practical application of knowledge (Kuenzi, 2008).

Expectations for meaningful curriculum reform, however, likely will be largely unrealized unless STEM initiatives are accompanied by significantly different ways to organize and deliver instruction. We are trying to fit STEM into what is basically still a separate subjects orientation to the organization of formal schooling. As we have briefly discussed, neither the coordinated nor the broad fields curriculum patterns are an easy fit with the existing separate subjects orientation and its link with the testing movement. Integrated learning itself implies a selective, irregular and iterative use of knowledge in contrast to the primarily linear, lock step, ends-means, separate-subjects instructional model that cumulates in testing. While the separate-subject curriculum model falls significantly short of tapping the full potential of STEM, we nevertheless have to find better ways to fit STEM into integrated programming.

How do technical orientated subjects in particular, such as vocational offerings in the high school or technology education courses in the middle school fit best within the STEM scheme of instruction? One way is to conceive of the purpose of instruction less as exposure to separate fields of content to be mastered and more as a correlating center of student experiences with the meaningful application of knowledge to activity. The instructional emphasis is on the academic integration of formal knowledge with technical content. Technical activity is used as a way to expose students to the thought processes involved in technical work, to correlate the teaching of other subject matter, and to enlighten students about how knowledge is generated and used. Students are fully exposed to the organizational as well as the substantive and syntactical structure underling knowledge and its use. The intellectual content embedded in activity is considered more important than potential skill-training use, although skill training continues to be a viable objective. An over-riding purpose of instruction is to provide experiences through which students come to terms with how knowledge is formulated and used to address technical applications.

To make the shift from a separate subjects emphasis, however, is a daunting challenge. It will demand new ways to think about schooling, its purpose, and the organization and presentation of instruction. The yet unrealized potential of the STEM initiative is that a new curricular reformulation will emerge that will more effectively expose students not only to the way that formal knowledge is learned but also in ways that it is applied.

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UNDER REVIEW

There is Power in a Union: The Epic Story of Labor in America
By: Dray, Philip, (2010).
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Abstract

Dray has provided us with an historic account of the labor movement in the United States from the industrialization of textile mills in Lowell, Massachusetts in the 1820's to the present day and beyond. He has done this through descriptions of individuals and details of many events, often confrontational and violent. Dray makes it clear that it has not been easy for workers to have their desires and needs fulfilled in the workplace. He also documents the influences within the labor movement that have served as ideals, distractions, and motivations. In addition to the 674 pages of text there are over 90 pages of end notes and indexes and 32 pages of photographs. The book is interesting to read and a reference for those who would investigate further.

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Review

Technology is broader than the machines, tools, and techniques used to make and service things. There is also concern for resource utilization, environmental impact, sustainability, and human interaction. It is within this framework that Philip Dray has written a comprehensive study of labor organizations. It goes well beyond a simple description of how workers have organized and the means they have used to influence decision making by employers, politicians, the public and those who control capital.

Lowell, Massachusetts was the first industrial city in the United States. The textile mills attracted young women from New England farms to the opportunity for a well paid job and the pleasures of factory life. The mills and accommodations for the women workers drew visitors, including President Andrew Jackson and frontiersman Davy Crocket, to see and admire this model of industrialization. However, long days (12 to 14 hours), smoke from whale-oil lamps, airborne lint, cuts in wages and raises in rent led to demonstrations and strikes. Mill owners appealed for the support of the community by characterizing the young women workers as ungrateful. Among those who sympathized with the women's cause were abolitionists who connected the morality of practices in the North with those in the South, "the lords of the loom and the lords of the lash". Gaining the understanding and sympathy of the public has been a repeated theme throughout the history of the labor movement and has often determined the success of the cases made by the disputing sides.

The struggle for public approval has been reenacted with workers in coal mining, shoemaking, railroads, steel-making, meat packing, and air traffic control, to name a few. Confrontations have played out in work sites, corporate offices, court rooms, legislative chambers, pulpits, and the media. Unions and those who would organize workers have often plead to the public for social justice. Owners have with equal vigor made their case against organizing workers by citing law, the negative impact on the public¹s interest, unreasonable demands, and employee ingratitude.

Political activism has been part of the labor story from early on. Some of the first factories provided housing and other necessities for their workers in a paternalistic manner. Essentially, few saw the need for workers to act collectively when employers took care of them. The friction often came when conditions were changed, such as production speedups, or, more recently, demanding that workers pay a larger share of the cost for their health care. The passage of laws to liberalize or restrict workers ability to bargain collectively, assure safe workplaces, strike against private and governmental employers, and have closed shops have gone back and forth in the halls of congress and state legislatures.

One of the plots in the political play has been the influence of communism in the labor movement. Many immigrant workers came to the United States from countries with communist governments. Others were idealistic about communistic principles which they saw as a means of bettering the lot of all workers. Others were less idealistic, opposed to authority, and more inclined toward rabble rousing. It was easy for critics to claim communist influences among labor unions and this was appealing to a public that had fear of insurrection. Much of this came to a head under the FBI leadership of J. Edgar Hoover, his extensive spy network within organizations of doubtful loyalty, and congressional hearings lead by Joseph McCarthy. Unions reacted in the extreme by half-heartedly supporting and sometimes removing suspicious members. Some early organizers were deported from the U.S. because they were considered to be threats to the nation. The labor movement compromised social justice goals in the effort to prove that it was "clean".

Elected politicians and candidates have often benefitted from the support of labor unions. Franklin Delano Roosevelt was a union favorite who even brought labor leaders into the White House to serve as advisors. Ronald Reagan, who was a former president of the Screen Actors Guild, offered high hopes for labor and gained their early support. These are two examples of political leaders who eventually came to displease many in organized labor. The Democratic Party came to take the support of labor for granted and Reagan and the Republican Congress managed to undo many of the gains that labor had made in the several preceding decades.

Labor unions have been inconsistent in their support of social justice for workers. Some unions were active in the abolition of slavery and readily accepted blacks and other minority members. Others held restrictions against racially mixed membership. In some cases there were parallel unions for racially different workers. But the divide was not always racial in that there were prejudices against late immigrant arrivals including the Irish and Southern and Eastern Europeans. Some employers seized on language barriers and biases to thwart the ability of workers to organize. The most recent immigrants frequently were willing to work for lower wages.

Worker's efforts to organize have often been accompanied by worker violence and militant action on behalf of employers. Many, on both sides of these conflicts, have died in confrontations and several in the labor movement have been executed. It often has been difficult to identify where the violence has begun but destruction has been one outcome. Violence by workers has included the use of guns, bombs, paving bricks, and fire resulting in the death of police officers and other defenders. Employers have used direct force to protect property or dissuade workers from strikes or other acts against their interests. Henry Ford hired a former boxer, Harry Bennett, to oversee what was called the "Service Department". Thugs under the guise of detective agencies or sheriff deputies have been brought in to "persuade" workers. National Guard, as well as Federal troops, have been used to protect replacement workers and to maintain peace. Perhaps the most tragic has been the execution of labor leaders who were caught up in the public's fear of further violence and insurrection and given a less than fair trial. Many of these claimed their own innocence and naively, perhaps, believed that the justice system would vindicate them.

Unsafe working conditions have been the incentive for many of labor¹s best efforts. Conditions and practices in the mining industry have regularly caused injury and death to scores of workers. Improved safety was a primary goal in the unionization of electricians. Manufacturing, construction, farm workers, and those in petrol-chemical employment, among others, have organized to reduce the risks of their work. Sometimes the hazards have been obvious but in many cases the effects of the working environment have not revealed themselves immediately. Such has been the case with asbestos, chemical pollutants, inadequate training, and work speed up. The United States Congress has enacted laws for the protection of workers including the Occupational Safety and Health Act and mining safety legislation. Provisions have been made for inspection and training workers about hazardous materials. However, support for safety legislation has been criticized for making the workplace less efficient. Reduced enforcement and the repeal of some laws has resulted.

The ranks of labor have not always been unified. Competing strategies for dealing with owners and making the cause for workers have been frequent. Militancy, advocated by some, has conflicted with compromise. Outspoken, dynamic leaders have gathered and persuaded followers to act as they would guide, often with negative affects. As union membership has declined and international competition has become more severe, decisions about union actions have become more difficult. The air traffic controllers, PATCO, underestimated the determination of President Reagan and overestimated their own indispensability resulting in the dismantling of that union. Similarly, meat packing members of Local P-9 at Hormel in Austin, Minnesota, acted against the advice of their national union (United Food and Commercial Workers) to accept wage cuts. Instead they followed labor consultant Ray Rogers, "the Muscleman of Labor" with resulting job losses. The extended P-9 strike enflamed the local citizenry and union actions were limited by National Guard troops sent in to protect replacement workers and property. In the meantime, Spam, one of the products of the Austin plant, became more popular than ever and corporate profits reached new levels.

Some of the more notable differences among unions have resulted from their basic organizational philosophy. The Commission for Industrial Organization (CIO) would represent all workers within an industry while the American Federation of Labor (AFL) organized workers within the same craft.

A lasting, joining of the two labor confederations was accomplished in 1955. Walter Reuther of the CIO and George Meany of the AFL, both union professionals, had very different personalities, but had reputations as ardent anti-Communists, an important quality at this time in the labor movement. Walter Reuther and his brother Victor were tool-and-die makers at Ford and worked for two years under Ford auspices in a Russian factory. They became disgusted with Russia's appeasement of Hitler and returned to the U.S. George Meany was an intimidating leader and super patriot who supported the anti-Communist oath required under Taft-Hartley. Reuther and

Meany were able to accept each other and lead their unions to join as one. In 1956 the AFL-CIO represented 33.4 percent of the non-farm workforce, the peak in union membership.

Dray¹s writing is enlivened by his recounting of many major events in worker rights history. In 1834, 800 Lowell, Massachusetts women textile workers struck against a 15 percent cut in wages. In New York City the Triangle Shirtwaist Factory was a nonunion shop mostly employing young women. It was located in the top three floors of the Asch Building. With exit doors locked to prevent theft, 146 panicked workers died from burning or jumping as flames engulfed the factory. At Carnegie Steel¹s Homestead Works gunfire, clubs, and knives were used to injure and kill strikers and opposing Pinkerton agents. At Ludlow, Colorado, miners and their families, evicted from company housing occupied a tent city. Escalating confrontations between miners, mine guards, Baldwin-Felts agents, and eventually the National Guard brought the deaths of 22 people. Following the Haymarket Square rally and trial in Chicago, five labor activists were hung. The public sought revenge for seven police officers who were killed. However, sympathies changed as biases in the trial were revealed. In a lengthy standoff between workers and employers in Lawrence, Massachusetts the Industrial Workers of the World (IWW) arranged to have children of striking workers sent away to sympathetic homes in order to lessen the economic burden on their families thereby embarrassing local citizens. Karen Silkwood, employed at the Kerr-McGee Nuclear Corporation became a whistle blower as she witnessed poor radiation safety practices. She probably was intentionally poisoned with plutonium and ultimately died in a suspicious automobile accident. Dray chronicles these and other historic labor events that shaped unions, influenced public opinion, and lead to legislative actions.

There is a richness in Dray's descriptions of prominent organizations and characters in the labor movement. The IWW, often called the "wobblies" was an early union with many impassioned leaders and members. Among those was Joe Hill, a Swedish immigrant merchant marine. His labor songs were written to inspire workers and build their confidence in the labor struggle. Though he professed his innocence, he was tried, sentenced, and executed by firing squad for a murder in Utah. Another wobbly was "Big" Bill Haywood, a one-eyed miner also known as a saloon brawler. He was the principal inspirational organizer for the IWW who was accused of conspiring in the murder of the former governor of Idaho and taken by nighttime extradition across the state line to face trial. He was successfully defended by Clarence Darrow and emerged as a folk hero who drew huge crowds as he continued to build the IWW. Carlo Tresca, another IWW organizer often spoke to striking workers in Italian confusing police spies about what had been said. "Mother" Jones, who raised the consciousness of the American public about child labor, traveled the country on behalf of worker causes. "I abide where there is a fight against wrong", she testified before Congress.

In more recent times John L. Lewis, who mined coal as a boy in Iowa, became president of the United Mine Workers. He was a bushy eyebrowed bristly man who advocated for mine safety and generally was a thorn in the side of conservative politicians. Cesar Chavez was able to organize farm workers, largely Latino, in an industry with workers on far spread farms. Gains for workers were achieved through consumer boycotts, picketing, sit-downs and other non-violent means. Dray acquaints the reader with these and many others who played roles in the shaping of the labor movement, including: FDR's Secretary of Labor, Frances Perkins, John D. Rockefeller, Jr. owner of western coal mines, Andrew

Carnegie, Samuel Gompers, Elizabeth Gurley Flynn, Emma Goldman, George Meany, Philip Murray, Henry Ford, Eugene Debs, W. E. B. Du Bois, Harry Bridges, Jimmy Hoffa, Lewis Pullman, A. Philip Randolph, Walter, Victor, and Roy Reuther are among those who Dray has used to tell the labor story. References to Presidents of the United States from Andrew Jackson to Barack Obama are included.

Dray raises the question, "does the American labor movement remain relevant enough to transition as it must?" The easy access to replacement and contingent workers as well as overseas production often has broken the loyalty of firms to their employees. The PATCO and Hormel strike experiences have been sobering for unions. As this review is being written, the governor and legislative majority in Wisconsin are poised to reduce the power of that state's public employee's union and perhaps set an example for other states to follow. Union members, not just those directly involved, have demonstrated with a level of vigor not seen recently.

There are some factors, as suggested by Dray, that will help unions to continue to represent worker interests. They need to take the high ground on issues of the length of the work week, underage employment, health coverage, and retirement. A global perspective can be facilitated by boycotts of sweatshop products, for example, benefiting workers in foreign locations where there are few labor regulations. Solidarity with other unions has been shown to be effective, particularly if the combine of workers are engaged in providing essential services. Gaining the approval of the public for the union's case is critical but difficult in tough economic times. Unions need to educate their members to be effective contributors in the workplace and in their collective future.

Dray has written a history of the labor movement in the United States. He has thoroughly researched events and presented them from the view of labor. Among other things, it is possible to trace the role of technology in the labor movement. The long record of interaction between workers and technology continues to evolve. Where does that interchange go from here? Are there parallels between the strength of labor unions, especially those representing non-governmental workers, and support for programs in technology in the schools? Those interested in education in technology will gain from the perspective presented by Dray.

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