Promoting Excellence in Preparation and Excellence in Practice

The Journal of Technology Studies

Volume XXXVIII
No. 1 Spring 2012
No. 2 Fall 2012

Technology

Past...

Present...

Future...

A refereed publication of Epsilon Pi Tau The International Honor Society for Professions in Technology.

The Journal of Technology Studies

A refereed publication of Epsilon Pi Tau The International Honor Society for Professions in Technology.

Jerry Streichler, Founding Editor and Publisher from 1977-2006

The Journal of Technology Studies (JTS) (ISSN 1071-6048) is the flagship, peer-reviewed journal of Epsilon Pi Tau, Inc., a nonprofit, academic and professional honor society. Headquarters and editorial offices are located at the Technology Building, Bowling Green State University, Bowling Green, OH 43403-0296. Use this address or jots@bgsu.edu for subscription matters or purchases.

The opinions expressed by the journal's authors are not necessarily those of the Board of Directors, staff, or members of Epsilon Pi Tau.

Two print issues per year are mailed to all members of the society upon request and to academic and general libraries around the globe. Issues that are published online only, the aforementioned printed issues, and past issues are available online at scholar.lib.vt.edu/ejournals/JTS.

The journal is currently indexed in Current Index to Journals of Education (USA), International Bibliography of the Social Sciences (IBSS) (UK), and the International Vocational Education and Training and Research Database at http://www.ncver.edu.au (Australia).

Separate articles or complete issues are also available in a variety of media forms from National Archive Publishing Company, P.O. Box 1346, Ann Arbor, MI 48106-1346, EBSCO Publishing, 10 Estes Street, Ipswich, MA 01938-0682, USA, and ERIC, 655 15th Street NW Suite 500, Washington, DC 20005, USA.

The JTS welcomes original manuscripts from scholars worldwide focused on the depth and breadth of technology as practiced and understood past, present, and future. Epsilon Pi Tau, as perhaps the most comprehensive honor society among the technology professions, seeks to provide up-to-date and insightful information to its increasingly diverse membership as well as the broader public. Authors need not be members of the society in order to submit manuscripts for consideration. Contributions from both academics and practitioners are equally welcome.

A general guide to the breadth of topics of potential interest to our readers can be gained by consideration of the 17 subclasses within "Technology" of the classification scheme of the Library of Congress, USA <lcweb.loc.gov/catdir/cpso/lcco/lcco_t.pdf>. This includes engineering and allied disciplines, informatics in its many manifestations, industrial technology, and education in and about technology.

Authors are strongly urged to consult the journal's "Guidelines for Authors," included in this publication, or available at the society's web site (www.epsilonpitau.org) or provided upon request. It provides additional details on the breadth and nature of topics of interest, the journal's scholarly writing standards, submission guidelines, and review and publication processes.

Printed in the United States of America by Kennedy Printing Company, Findlay, Ohio.

Table of Contents

Volume XXXVIII, Number 1, Spring 2012

Historiography in Graduate Technology Teacher Education

Jim Flowers & Brian Hunt

Abstract

A proposal is made suggesting the inclusion of historiography (i.e., historical research and the writing of history) into graduate technology teacher education. In particular, a strategy is forwarded to have graduate students in technology teacher education, who are working at schools in different locations, conduct historical research and write histories describing how local inhabitants transmitted technical learning dating back to the earliest human inhabitants. There are potential benefits for the graduate students, the students they teach, and the field of technology teacher education. Collaboration among institutions is recommended. After arguing for the proposal, this article uses a personalized historical narrative approach to evoke a connection with the reader that is not possible with more impersonal approaches and thus illustrating some of the richness of historical techniques.

Keywords: Technology Teacher Education, Historiography, History Education

Historiography in Graduate Technology Teacher Education

It is common to see a course in the history of technology education at the graduate level. It is not common, however, for graduate students knowingly to engage in historiography, or original historical research and writing about their field. The purpose of this article is to suggest an active rather than passive approach to history in graduate-level technology teacher education. Students would engage in the uncovering of historical information, make original analyses of this history, and write an original historical account of formal and informal technical and technology education in their locality. The suggestion is not for students to look at the history of technology or technical artifacts, but for them to synthesize information and uncover new historical information about the local history of formal and informal education about technical content. In doing so, they may ask questions such as, "How did the first Native Americans in the area pass on knowledge of different technologies to future generations?" and "What effect did teaching industrial arts only to boys in the 1940s have on a girl's relationship with technology?"

This article takes two paths to make a case for the inclusion of historiography in graduate technology teacher education. The first is a rationale for the proposal grounded in the literature. The second part provides a brief personal narrative from the second author, followed by the first author's biographical account of the development of this idea, including an example of integrating historiography into a graduate course. This is not a case study, but a personal narrative, similar to an oral history. It is included in an attempt to illustrate the power this method can have in evoking a connection between the reader and the authors. This technique is not common in the academic literature of technology education, though it can offer a richness not seen with other techniques. Because the authors advocate that students uncover often first-hand historical accounts, it was fitting to use the personal narrative technique.

A Rationale for Historiography in Graduate Technology Teacher Education

Often technology educators laud their profession as a "hands-on" field where students learn by doing. However, regarding the study of history within technology education and technology teacher education, learning by doing does not seem to have been emphasized, as evidenced by the lack of literature on this subject. After all, those who learn about hundreds or thousands of years of history have themselves only been alive for a matter of decades, so is it appropriate to suggest that these students should actually "do history" by creating historical works rather than merely learning historical information and reading the historical analyses others have performed?

Galgano, Arndt, and Hyser (2008) suggested that history not be thought of as "a collection of facts about the past . . . it is an interpretation of the past based on the weight of the available evidence" (p. 1). Historiography can be thought of as the research and writing of an original work of history: "The process of critically examining and analyzing the records and survivals of the past is here called historical method. The imaginative reconstruction of the past from the data derived by that process is called historiography (the writing of history)" (Gottschalk, 1969, p. 48).

The study of history does not necessarily entail that students actually write history, or as might be said, that they actually "do history." However, Loewen (2010) suggested that "history comes alive when students do, rather than merely read, history" (p. 83). He spelled out some typical processes this entails:

> Doing history, broadly defined, means identifying a problem or topic, finding information, deciding what sources are credible for what pieces of information, coming to conclusions about the topic, developing a storyline, and marshaling the information on behalf of that storyline, while giving attention to information that may seem to contradict the argument. (p. 83)

Although historiography includes several techniques of investigative reporting, it also requires historical reasoning and making connections between what is uncovered and other events outside the narrow field of investigation.

When students study history, it might at first seem like a collection of names, dates, and events. However, just as Bloom's Taxonomy (Bloom, Mesia, & Krathwohl, 1964) of the cognitive domain includes six levels from knowledge to evaluation, the study of history can be an increasingly rigorous and rich undertaking. Fallace (2009) argued that historical knowledge includes not just an understanding of facts, but of how the facts were constructed; he suggested that "historiographical knowledge will allow teachers to provide a more accurate view of the epistemological value of history, and that teachers will pass this knowledge to their students" (p. 206). Even without asking students to engage in historiography, a sound study of history provides a rich atmosphere where students analyze and question what has been written about history. Engaging in original historiography goes far beyond this: it includes finding previously unsynthesized historical data and making the connections.

Does it make sense for students to write history? Shouldn't that be what learned historians do? If a technology education teacher is asked in any way to play the role of a social studies or history teacher, we can look to social studies teacher education for models to aid in the preparation of technology teachers. Hoefferle (2007) noted her initial reluctance to teach undergraduates historiography, but concluded from her experiences that "historiography can be relatively easy to teach and learn at the high school and undergraduate levels" (p. 42). She cited its value in terms of critical thinking. After teaching historiography to undergraduate preservice social studies teachers, Fallace (2009) noted, "the course was more successful at breaking down the 'compartmentalized thinking' between discipline and pedagogy [than at] closing the 'breach' between . . . preservice teachers and historians" (p. 210). In this case, the students were becoming history teachers, so they were practicing that about which they were teaching. Blaszak (2010) asked preservice teachers "to 'do' some history using only archival primary sources" (p. 438) and later had them consider the reasons different student authors took different paths. We advocate the use of historiography for graduate students in technology teacher education; Johnson (2005) concluded there are several advantages for using historiography in graduate education:

> It serves as a continuum connecting past, present, and future that links all aspects of the discipline. Second, historiography trains the student to think historically over broad spans of time—a tool that can then be applied in their other courses and in their own research. Third, it challenges students to link themes, trends, methodological approaches over the breadth of time to see cause and affect within the spectrum of historical writing. (p. 528)

Those situated within a field may find it difficult to address the history of that field objectively due to their personal biases, their inability to realize that their own experiences are not necessarily those of others, and their unwillingness to convey or even acknowledge historical information that may portray the field unfavorably. Instead of objectivity being the goal, it is possible to leverage the subjectivity of the student/author. Munslow (2010) held that history is not "exclusively or even primarily empirical in origin, because it is a representation, history is an art form that asserts, argues, suggests and represents from a position or standpoint rather than provide objective meaning" (p. 108). It could be that an author's professional and emotional connection to a field can lead to insights regarding the history of the field that might not have otherwise emerged. However, it is also possible for the historical researcher to allow subjectivity to add too much of the author to the historical account; Bailyn (1994) suggested that this particular anachronism is a universal problem in the writing of history: “All historians are involved in this question; namely, whether or not one’s present views are read back into the past and, therefore, whether the past is distorted, foreshortened, and its distinctiveness lost” (p. 50).

Learning to Write History

A new historian in any field may attempt to learn the correct way to write about history. But rather than approaching this convergently and seeking a single correct method, we might instead suggest that the new historian use several techniques, approaches, and tones. As Commager (1965) asserted: “There is no formula for historical writing. There are no special techniques or special requirements, except the technique of writing clearly and the requirements of honesty and common sense” (p. 37). Although the writing of meaningful histories can take many forms, Commager (1965) identified some typical patterns for such writing: chronological, geographical, political, cultural, institutional, and biographical. If secondary students are asked to show how personal communication devices have evolved during their lifetime, they might use a chronological approach; if technology teacher education graduate students uncover the ties between the history of education about technology and its impacts on gender-role stereotypes, they are likely taking a cultural approach, at least in that part of their historical writing.

Historiography can also be taught by having students first contrast different historical accounts. DeRose (2009) put together an activity for his high school students that involved looking at American History textbooks written during the last 200 years. The students were asked to consider how different historical accounts were written in several textbooks from the time of the event until the present time. The students noted that most of the accounts were similar but all differed slightly with respect to the author. One area of more notable differentiation by the students was about U.S. President Harry S. Truman’s firing of General Douglas MacArthur. In a textbook written shortly after the incident, the author was critical of Truman’s decision; yet in later textbooks, authors favored Truman’s decision. This is not to say that the writing of history should be affected by the proximity of the event but that views often change over time.

K-12 Education

We propose that historiography be included in graduate technology teacher education (as outlined near the end of this article.) However, one outcome of that inclusion may be a richer teaching approach that more readily integrates history and historical methods for K-12 technology education students because these teachers may have a greater understanding and appreciation of the methods used to research and write history. The integration of science, technology, engineering, and mathematics (STEM) has been at the forefront of literature in technology education of late. For example, all five articles in the most recent issue of The Journal of Technology Education (Vol. 23, No.1) address STEM education, even though this was not a themed issue. Technology education students also study science and mathematics, and the push to integrate meaningful grade-appropriate education from these areas abounds in the recently published curriculum and literature of the field. However, technology education students study more than the STEM disciplines (Flowers, 1998), and it is possible to integrate their other studies into a study of technology. In particular, they also study history.

The existence of one or more K-12 standards for students in history or social studies is not sufficient for justifying the need for technology education teachers, themselves, to meet that standard. However, this does provide support for a technology education curriculum that integrates those social studies standards. National standards for K-12 students in history (National Center for History in the Schools, 1996) include standards for historical thinking. Among these is Standard 4 for students in Grades 5-12: “The student conducts historical research” (p. 68). This standard is divided into the following expectations:

A. Formulate historical questions from encounters with historical documents, eyewitness accounts, letters, diaries, artifacts, photos, historical sites, art, architecture, and other records from the past.

B. Obtain historical data from a variety of sources, including: library and museum collections, historic sites, historical photos, journals, diaries, eyewitness accounts, newspapers, and the like; documentary films, oral testimony from living witnesses, censuses, tax records, city directories, statistical compilations, and economic indicators.

C. Interrogate historical data by uncovering the social, political, and economic context in which it is created; testing the data source for its credibility, authority, authenticity, internal consistency, and completeness; and detecting and evaluating bias, distortion, and propaganda by omission, suppression, or invention of facts.

D. Identify the gaps in the available records, marshal contextual knowledge and perspectives of the time and place in order to elaborate imaginatively upon the evidence, fill in the gaps deductively, and construct a sound historical interpretation.

E. Employ quantitative analysis in order to explore such topics as changes in family size and composition, migration patterns, wealth distribution, and changes in the economy.

F. Support interpretations with historical evidence in order to construct closely reasoned arguments rather than facile options. (p. 68)

In addition to these standards for history, the curriculum standards for high school social studies identified by the National Council for the Social Studies (1994) include the following:

> Social studies programs should include experiences that provide for the study of the ways human beings view themselves in and over time, so that the learner can: . . . systematically employ processes of critical historical inquiry to reconstruct and reinterpret the past, such as using a variety of sources and checking their credibility, validating and weight evidence for claims, and searching for causality. (p. 34)

The idea of asking secondary school students to write local histories is not new. Stevens (2001) recalled that when he began teaching history at a junior high school in 1978, there were many local histories of Rye, NH, that had been written by eighth graders. Stevens' text, which is a primer on teaching secondary students local historiography, including the writing of local history, could be a valuable source for graduate students faced with a local history task.

Technology education teachers can integrate history and social studies into their curriculum. This allows technology education teachers to leverage the learning and experiences students gained in working toward those standards in their social studies classes. In particular, a technology education teacher who has personally engaged in historical research and the writing of history would likely be better prepared to integrate content that supports these history and social studies standards and to address Standard 7 from the Standards of Technological Literacy (ITEA, 2007): "Students will develop an understanding of the influence of technology on history" (p. 79).

Pannabecker (1995) suggested that within the history of technology education, a narrative approach seems at odds with a systems approach, though he believed both are needed. Although a systems approach may, for example, show how successive cultures used different systems to achieve certain needs (or in this case, certain needs for technical education), a narrative approach might convey both the interconnectedness among forces in the environment and an emotional connection by people of a given time.

Could engaging in historiography influence a teacher's approach to his/her own content area? Possibly. Pannabecker (1995) contrasted internalist, externalist, and contextualist approaches to the history of technology (not technology education) in a way that has implications for technology education. Though the internalist, he claimed, would consider technological artifacts primarily in view of the history of the design of those artifacts (as in the evolution of the bicycle), externalists may see the artifact as a mere instance or example in the primary discussion of social and political change (e.g., the impacts on society). A contextualist might include both the elements of internal product design and complex and changing interactions with several factors of society. A graduate student who engages in a historiographic journey in the field of technology education may tend to have the more holistic contextualist approach because of the variety of information and connections that would be examined. It could be that information that was key to an alternative approach troubled a student so much, that, for example, it became impossible for the student to address the curriculum changes of the past adequately without trying to understand how the Great Depression and two world wars impacted that curriculum, and without considering how that curriculum influenced the local workforce and the quality of life for local inhabitants. A teacher who has faced such interconnected and confusing information in graduate education may well be apt to do more for her or his K-12 students than to end a design lesson with, "Oh, and brainstorm the impacts on society from this technology."

One of the aims of graduate education is to prepare researchers in a field. Petrina (1998) recorded that of the 96 examples of research methods in the first eight volumes of the Journal of Technology Education, there were six (5%) instances of "historical" and one instance of "methodological (historiography)" (p. 35). He concluded that "JTE comes across as a text where conservative voices are favored and critical voices are the exception" (Petrina, 1998, p. 51.) Of the 16 categories of research methods he used, it could be argued that those related to historical research may tend to favor conservative voices of older researchers over the voices of those who are younger. But in a field where more research and more critical voices are needed, it might be that an emphasis on historiographic methods in graduate technology teacher education could influence a change.

Our Journeys

Although it is not customary to include a biographical narrative showing the emergence of an author's idea, it seems informative in this instance, although it must be treated as anecdotal. After all, this account is actually the written history of the idea's development, that is, a biography illustrating a bit of micro-historiography to show how it may evoke a different relationship between the reader and the content.

A Student's First Step toward Historiography

As the coauthor of this article, I remembered an undergraduate perspectives course that examined how technology had influenced humans and how humans have affected technology. One assignment in that class stuck with me: it was to research the history of Thomas Midgley and make a stand on his behalf. I read previously written works and found conflicting stories about a great inventor, an environmental killer, a mastermind of two evils, and a great asset to two industries. I soon discovered the reason for the conflicting stories was the dates of the articles. Midgley discovered that Freon was a great refrigerant and that by adding tetraethyl lead to gasoline he could boost the octane of the fuel increasing performance and fuel efficiency. When these discoveries were initially made Midgley was a hero; later when the environmental and safety issues behind Freon and leaded gas were discovered, Midgley was no longer a hero. I think I remember this best because I had to dig and find the information on my own but moreover that I had to interpret and evaluate that data to make a stand on his behalf. Although most of my work was historical analysis, I believed I had found something new that was worth sharing with others. This was a first step toward historiography for me, and it was empowering. But it did not push me to see myself as a writer of history where I could actually add to our society's historical knowledge.

An Instructor's Journey

I have been involved with technology education and industrial arts for several decades. I found myself newly assigned to teach a long-standing, online, master's level course on the History and Philosophy of Technology Education. The graduate course was to be taught to those majoring in an online master's program in technology teacher education. This program appealed to working K-12 technology education teachers from across the United States who were place-bound and unable or unwilling to relocate to a university to pursue graduate studies. They are situated at schools and within communities in a variety of states in the USA.

With a background that included a degree in philosophy, I have never considered myself to be an insider in the field of technology teacher education, but one who is more apt to offer criticism. Our field has a rich history, with many notable figures and movements; frankly, I felt out of my league when I learned I had been assigned to this class. Both my lack of knowledge of the history of the field, and my difficulty in promoting any current school of thought, or "party line," as I called it, were problematic.

To prepare to teach this online graduate course, it made sense for me to consult many resources and to learn about the rich and varied history of the field, along with the different philosophical underpinnings. But I was still not willing to be a "sage on the stage" and to base the course content largely on my knowledge of these areas. I didn't feel authentic in providing direct instruction that mirrored, say, the "This We Believe" document (ITEEA, n.d.), where a creed of the field is forwarded. Slogans such as "Technology for All Americans," "Technology Education, The New Basic," and even "Project Lead The Way," seemed to each be incorrect if I logically considered what those words said (Flowers, 2010).

Moreover, I had never actually been a fan of history, other than watching movies about wars. Social studies had been my worst class in high school, and the need to remember names, dates, and historical events seemed so far removed from my life that the motivation to learn was often absent. Decisions affecting the future seemed much more important. The fact that this field itself deals with technology, a rapidly changing area of study, reinforced my emphasis on the present and future. I even wrote once that it might be a mistake to ask undergraduates in technology teacher education to study the history of their field, as this may root them too solidly in the past (Flowers, 1997.)

After wrestling with the idea of providing direct instruction so that students would learn about the different philosophies of the field and about the history of the field, I came upon a different approach.

A Different Approach

Instead of teaching students what the philosophy of the field is, would it be possible for me to teach them to philosophize regarding technology education? That is, instead of teaching so they would learn philosophical content of the field, could I teach in a way that would first assist them in understanding philosophical processes and second to have them use those processes regarding the field? My background in philosophy would be a distinct asset. I could even use the Socratic method with these students as their understandings became better and better honed. In the course of doing this, quite a bit of the comparisons among historical eras could emerge. Delving deeply into an idea sometimes requires the learner to look at the history of the idea, and that approach to history was palatable.

If this approach were possible for addressing the philosophy of technology education (i.e., not just learning about the philosophy of the field but doing philosophy in the field), might it also be possible regarding the history of technology education. Could I ask students to play the role of a historian or a writer of history? Could I help them engage in original historical research? It would entail learning about and helping them use processes of historical research and writing, but if this were possible, might it become an empowering experience that helped them develop not just knowledge of history, but a personal relationship with it?

The Assignment

In the first semester this plan was implemented, this "local history" assignment charged each of the graduate students to compile an original history of formal and informal technology education and technical education in their geographic region, dating back to the earliest human inhabitants. Elsewhere in the course, materials related to the history of technology education were presented to students. They also worked on a separate assignment to report on a single historical movement in the history of the field. However, for the local history assignment, they were for the first time playing the role of the researcher and writer of history, rather than the role of the consumer of historical information.

Online learning materials were developed to assist students in historical research methodology. Topics included: the roles of historians; the scope of historical research; getting assistance in historical research; sources for historical research; assessing sources of historical information; using media in historical research; oral history methodologies; analysis and synthesis of historical information; and writing history. These can now be seen in a unit on historiography in technology education (Flowers, 2011). In addition, students were asked to participate in online class discussions addressing problems and issues that arose during this activity.

The work of each of these graduate students began with planning their own methods. They had to find out what historical information was available, and this included looking through yearbooks, old curriculum guides, old newspapers, information from historical societies, books on the history of the area, and more. They also planned to speak with key individuals. But when they started to uncover historical information and piece it together, the activity took on a life of its own. When these students looked through pictures from the past about local schools 80 years ago, when they found information about industrial training at a factory 120 years ago, or when they talked with someone about the history of early Native American cultures in the area, the information would raise questions that sent them in directions that seemed to multiply at every turn. Students' interests and own character became evident: some would explore connections to world events (e.g., world wars) or make connections to local events (a new industry coming to town); others would look at the plight of the teacher and student, the town's economics, or how discrimination was evidenced. Each student synthesized what was uncovered and learned, drawing conclusions about the overall evolution of formal and informal technology education and technical education in that locality up to and possibly beyond the present time. Part of what made this so difficult was the tendency to follow fascinating side roads where interesting historical information was uncovered that had little to do with the history of technology education and technical education, and students were encouraged to add such information to an overflow document that they could revisit later. The principle result was a separate historical account, published online by each of the students to their university webserver account; they were careful not to violate copyrights or the rights of those pictured or discussed.

Reactions to Initial Implementation

As the instructor, I can anecdotally report that this activity soon developed its own momentum, as students seemed to find internal motivation. They reported that they saw themselves as playing a role in preserving a historical record. Many noted that they were seen by school colleagues as the "resident expert" on local history.

Of special note are two comments from students. The first of these was in reference to an elderly subject who was interviewed, but who passed away just weeks after the interview; the student researcher attended the funeral, and shared with others there some of the wealth of information he had gained during that interview. He remarked that this was a unique and precious opportunity.

However, two other students complained of a problem in the design of the activity. It had been noted that this was a class-based report assignment, and was not intended to add to the historical record of the field by producing publishable information, as that would have entailed prior review by the institutional review board (IRB) for human subjects research. These students were frustrated at having put forward so much effort and care for this project, only to find that it would be inappropriate for them to add it to the historical record.

Therefore, a revised approach was developed and used in three later semesters. The students were required conduct interviews to gain oral histories, but to first go through human subjects research training and to submit research protocols for the human subjects portion of their local history activity. This covered, for example, the interviews they conducted, but not data that might have been gathered from the materials stored at their local historical society repository or library.

Outcomes

It could be argued that the local history of technical education is neither rich nor important. However, this activity can work as a lens through which students make connections with a wide variety of meaningful history. Although they were not all done under the auspices of the IRB, by the time of this writing, 46 local histories have been written from students in 10 different states. In some instances, students learned of the impact of early industries on technical education in their town. They saw evidence that African-American teachers were paid less than White teachers during the days of racial segregation. Classes that were for males only were a surprise for some to uncover, but hearing an elderly women speak of what that meant to her when she was a girl seemed to grip them. Seeing how both world wars impacted the nature of Industrial Arts curriculum raised issues of national needs and societal responses to particular crises through educational initiatives. Because this activity expected them to extend back to the earliest human inhabitants, and to consider nonformal technical education, there were ample opportunities for cultural appreciation.

Teachers should appreciate complex historical connections. The Standards for Technological Literacy (ITEA, 2007), suggest that technology education teachers ought to facilitate K-12 students in historical studies related to technology as a driving force; recall: "Standard 7: Students will develop and understanding of the influence of technology on history" (p. 79). Pannabecker (2004), however, suggested, "We must avoid teaching a simplistic ideology of 'effects' and a timeline of decontextualized artifacts and processes portrayed as a canon with a predictable, linear trajectory . . . Teaching a contextualized heritage will increase the field's capacity for reflection and analysis" (p. 80).

Later offerings of the class resulted in many benefits. For example, planning greatly improved. Students developed successive draft IRB proposals that were continually refined by comments from the instructor. When they met the instructor's criteria for approval, the students were cleared to submit these to the IRB, with the instructor signing as a faculty sponsor. A second benefit was that some students tended to look at their undertaking as something greater than the course. In later discussions with the instructor, it emerged that some students began to see themselves differently in relation to the field and its history. They had become some of those people who write the history of the field and the history of their town. This type of empowerment is not new to graduate education, though it may be unusual for it to emerge in the area of the history of the field. Several students noted at the end of the course that their reports were gratefully accepted as an addition to their local library or local historical society. A third benefit was reported long after this experience. The instructor of these students' research methods course noted that the learning and experiences associated with the local history activity were evident when the students participated in this class.

This activity also inspired the instructor: I used to shun history, and I now find it fascinating and captivating. I gained a new-found love of historical information as a direct result of guiding students through their experiences of unearthing and interpreting historical data. I became fascinated with the earliest issues of Industrial Arts Magazine and how some their contents from the time of World War I seemed amazingly appropriate for the present time. I also became fascinated for the first time with personal genealogy; even cemeteries were seen as historical data repositories rather than graveyards. In short, the excitement for historical research and thinking was contagious, changing both my relationship to the field in which I had been working for more than 20 years and my very world.

A Proposal

Even though there have been benefits to students from this activity, it might be that collaboration among institutions could be of benefit to the field. A proposal is therefore made to other teacher education faculty who address the history of technology education and technical education in their graduate programs, especially those that offer degrees through distance education that have learners situated in different communities working at schools. If a similar undertaking takes place at a variety of institutions, it may be possible to compile the information graduate students have generated, where they have given their permission, to form a richer picture of the history of the field in a regional, national, or international scope. This would further be supported by asking students to publish their work online, and after the course has ended, requesting their permission to allow the institution/instructor to archive a copy for distribution from the institutional web server. A national referatory could then point users to the locations of these documents.

Conclusion

There may be advantages in including historiography in graduate technology teacher education curriculum. This article began by explaining a case for this inclusion based on the nature of historiography and of the field. It then switched to a biographic narrative to illustrate a change in perspective that might be seen in actual historiography, invoking different reactions from the reader. Even though connections can be made to the nature of technology education and to secondary school history standards, it has also been shown that one instructor's personal path of revelations in teaching historiography has made a difference for him and his students.

For those who teach a graduate course in the history of technology education, or in the history of other areas of education, a proposal is made. First, can these classes include historiography and the writing of local histories of the field by students in these classes? Second, if that is possible, then can these local histories be compiled to become a larger mosaic that facilitates even greater levels of comparisons, cultural awareness, and historical understanding?

Further research on the inclusion of historiography in graduate technology teacher education could consist of studies to determine in what ways technology education graduate students apply their learning about historiography in their later teaching. The attitudes of these teachers can be compared to those who had not engaged in historiography, comparing in particular their appreciation of history, their feeling of connection to it, their ability to be critical of historical information, and their self-image as a writer of history. Future research can also examine the impact on K-12 student learning outcomes in history after historical content and methods are addressed in technology education classes.

Graduate technology teacher education students could work together to create a "Wiki" history of technology education adding new facts from their geographic location and editing the document to fit the times, as new history is created every day. This could be expanded beyond technology education to include all areas of education. A national referatory could serve to preserve historical information, allow connections to be made, and influence the very nature of the field and the views of those in the field.

Dr. Jim Flowers is a Professor and Director of Online Education in the Department of Technology at Ball State University, Muncie, Indiana. He is a member of Beta Chapter of Epsilon Pi Tau.

Mr. Brian Hunt is a Graduate Research Assistant in the Department of Technology at Ball State University, Muncie, Indiana.

References

Bailyn, B. (1994). *On the teaching and writing of history.* Hanover, NH: University Press of New England.

Blaszak, B. (2010). Preventing "back-atcha": Improving secondary school instruction by introducing prospective teachers to historiography. *The History Teacher, 43*(3), 435-439.

Bloom, B., Mesia, B., & Krathwohl, D. (1964). *Taxonomy of educational objectives* (Vols. 1-2). New York: David McKay.

Commager, H. (1965). *The nature and the study of history.* Columbus, OH: Merrill.

DeRose, J. (2009). Back to the future with textbooks: Using textbook passages from the past to help teach historiography. *The History Teacher, 42*(2), 229-237.

Fallace, T. (2009). Historiography and teacher education: reflections on an experimental course. The *History Teacher, 42*(2), 205-222.

Flowers, J. (1997). Teaching the historical perspective—Should we or shouldn't we? *The Technology Teacher, 57*(4), 7-8.

Flowers, J. (1998). Photography: An integrated technology education approach. *The Technology Teacher, 58*(3), 23-26.

Flowers, J. (2010). The problem in technology education (a definite article). *Journal of Technology Education, 21*(2), 10-20.

Flowers, J. (2011). Teaching historiography. Retrieved from http://jcflowers1.iweb.bsu.edu/rlo/mod historiography.htm

Galgano, M., Arndt, J., & Hyser, R. (2008). *Doing history: Research and writing in the digital age.* Boston, MA: Thompson.

Gottshalk, L. (1969). *Understanding history: A primer of historical method.* (2nd ed.). New York: Knopf.

Hoefferle, C. (2007). Teaching historiography to high school and undergraduate students. *OAH Magazine of History, 21*(2), 40-44.

International Technology Education Association [ITEA]. (2007). *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author.

International Technology and Engineering Education Association. (n.d.). *This we believe.* Reston, VA: Author. Retrieved from http://www.iteea.org/AboutITEEA/ThisWeBelieve.pdf

Johnson, C. (2005). Herodotus who and annals what? Historiography and the history student. *Rethinking History, 9*(4), 521-528.

Loewen, J. (2010). *Teaching what really happened.* New York: Columbia University Teachers College Press.

Munslow, A. (2010). *The future of history.* New York: Palgrave MacMillan.

National Center for History in the Schools. (1996). *National standards for history.* Los Angeles: Author.

National Council for the Social Studies. (1994). *Expectations of excellence – Curriculum standards for social studies.* Silver Spring, MD: Author.

Pannabecker, J. (1995). For a history of technology education: Contexts, systems, and narratives. *Journal of Technology Education, 7*(1), 43-56.

Pannabecker, J. (2004). Technology education and history: Who's driving? *Journal of Technology Education, 16*(1), 72-83.

Petrina, S. (1998). The politics of research in technology education: A critical content discourse analysis of the *Journal of Technology Education*, volumes 1-8. *Journal of Technology Education, 10*(1), 27-57.

Stevens, R. (2001). *Homespun – Teaching local history in Grades 6-12*. Portsmouth, NH: Heinemann.

Following Engineering Graduates

Michael Feutz and Richard Zinser

This study provides an in-depth analysis of recent graduates' experience with completing an engineering technology program and entering the profession. It is unique because the study was conducted on a baccalaureate-level program and because it helps fill a gap in the literature. The phenomenological method was used to obtain qualitative data to understand the personal meaning of the process for the participants. Findings include positive perceptions about the curriculum and faculty, and some areas for improvement. The graduates found personal meaning especially in their capstone course and by being involved with the engineering student organization. There are implications for program evaluation and educational leadership.

Key words: program evaluation, phenomenology

The purpose of this study was to investigate the phenomenon of industry-employed graduates of the Bachelor of Science in Heating, Ventilation, and Air Conditioning (HVAC) Engineering Technology at Ferris State University (FSU) in Big Rapids, Michigan. In particular, the research sought to learn what the educational experience meant to the graduates, how they perceived they were prepared for work, what they consider to be the essential elements of the program, and what changes they would make to improve it. Most studies of Career and Technical Education (CTE) programs are quantitative in nature (Bozick & Macallum, 2002; Bragg & Russell, 1993; Brown & Conbere, 2005; Coryn, Gullickson, & Hanssen, 2004; Kagaari, 2007; Rahn, O'Driscoll, & Hudecki, 1999) and focus on descriptive statistics such as enrollment, retention, graduation rate, and employment rate. However, efforts to collect data related to how graduates apply their learning on the job and how they impact their place of employment are often neglected due the constraints of time and money (Zinser, 2003). Given the role of CTE to prepare students for success in the world of work, data related to graduate performance on the job might be more significant than statistical counts of student numbers, or student performance in school, in regard to curricular improvement. In many cases the industries that CTE programs serve are relatively unique so there may not be a benchmark against which quality can be measured; in that situation each program would need to be evaluated as a separate case, although a similar process may be used for different industries.

The Bachelor of Science in HVAC Engineering Technology does not fit neatly into any one-career cluster or serve a major industry. Created in the mid-1980s for a specific industry sector, it was designed to be more application oriented compared to a general engineering program, making it unique in higher education. In addition, it is a baccalaureate-level degree, whereas most CTE programs are placed at the high school and associate degree levels. The market for which it prepares students is not local or even regional; it is national and occasionally international in scale, yet the program itself is relatively small. Graduates accept jobs at companies that vary widely in size and scope; some have less than 10 employees and serve a local market while others have thousands of employees with branches throughout the world.

Similar to other institutions, FSU collects internal assessment data in the form of Academic Program Reviews; the last one conducted in 2006 indicated a high level of quality as perceived by key stakeholders, including students, graduates, employers, faculty, and advisory committee members. Participants responded to typical survey questions and provided short, one-sentence comments for a number of open-ended questions. The data provided by the Academic Program Review was mostly positive and provided a basic quantitative measure of stakeholders' perceptions of quality. Responses to open-ended questions provided supplementary information, but sufficient data were not available for analysis. Further, the use of a simple survey instrument is inadequate for additional probing and in-depth questioning. In order to gain a better understanding of how quality in the program is achieved and what opportunities exist for curriculum improvement, a more in-depth analysis using a qualitative design was necessary.

Background Literature

Program Evaluation

Evaluation is a process that determines the worth of something. In education, evaluation is commonly used to assess the value of specific courses for students. Rarely however is a complete program submitted to a rigorous evaluation by external standards. Yet most technical education degree programs have a built-in accountability to the community that hires its graduates; the curriculum and equipment must be kept up to date according to what is used in the industry. Evaluation therefore can serve as an audit of a program to solicit ideas for improvement and to resolve any problems (Zinser, 2012). The procedures for conducting evaluation studies vary along a spectrum of complexity. An evaluation could be mostly informal such as asking students how they are doing in the program; second, the process might be semiformal by including discussions with an advisory committee or representatives from the related industry; third, a formal evaluation is sometimes conducted by an external reviewer much like a research project. Similarly, what gets evaluated can range from a single course to the entire system required for the program to function: funding, facilities, curriculum, faculty, student participation, learning objectives, and final outcomes such as employer satisfaction with the graduates. Many different data collection methods can be used, depending on the aspect of the program under study.

An evaluation approach that has been used in industry for many years is the four-level valuation developed by Kirkpatrick (1994). Although it was designed for corporate training programs, not necessarily for education, there are some similarities that can be readily adapted.

1. **Reaction:** measures how the participants liked a specific learning experience; it could include their perceptions about the teacher, the content and methods, and even logistics such as the facility and schedule. The participants should have positive reactions in order to motivate them to continue learning about the topic and to use the skills in practice. Student opinions are typically measured with simple feedback forms at the end of the course and the results are generally used informally by the instructor to make adjustments as necessary.

2. **Learning:** measures how much the participants improved knowledge, increased skills, and changed attitudes resulting from a course. The assessment of learning is the most common evaluation method used in education, for which educators have considerable expertise. Teachers use a variety of written tests to measure specific learning objectives especially at the knowledge level. The assessment of skills is more widespread in technical subjects and is accomplished through performance demonstration by the learners. Measuring student attitudes is less common, perhaps due to the intangible nature of the affective domain; however, an attitude such as safety is important in technical education and can be measured indirectly by observation of specified activities.

3. **Behavior:** measures the extent to which students changed their behavior as a result of the educational experience. (It actually focuses on job performance, not "behaviors" like attendance.) To measure behavior it may be difficult to isolate the effects of the training because of other variables such as learner motivation, the work procedures, and organizational climate. This evaluation level is more challenging and time-consuming because it requires follow-up with participants after the training, but such an analysis can provide meaningful feedback about the program. By asking former students how they perceive they were prepared for work, faculty may discover that students believe there are some gaps and some redundancies in the curriculum, for example, which could be easily corrected. Evaluating behavior is best done through pre- and post-measurements of performance and by conducting interviews with the participants and their supervisors.

4. **Results:** refers to the actual benefit for the organization from the educational experience and is usually expressed in "bottom line" measurements such as reduction of errors or increased profits. Although this may be the most important level for the employer, it is also the most challenging to quantify the results of education. In the context of program evaluation, however, employers usually expect that graduates have the right skills, which reduces their training cost, and that the number and quality of prospective workers has increased. Evaluators of a program must utilize well-defined success criteria to demonstrate its value, and when a program is regarded as successful, the organizations are very likely to support the program and even increase their support.

Knox (1998) developed a comprehensive model for program evaluation involving eight stages, coordination, and interpersonal considerations. This process is similar to project management in general, but the key concepts for the current discussion are the identification of stakeholders and agreement on exactly what should be measured (or the success indicators). For technical education, external stakeholders are usually the employers who hire the program's graduates, and the measures of success are the sufficient number and quality of prospective employees. The data collection methods are then chosen depending on the nature of the data source. For example, student or graduate perceptions are commonly measured by surveys, interviews, and focus groups. Advisory committee members or other experts who employ the graduates are usually interviewed. The curriculum can be assessed by comparing its objectives with professional content standards.

Therefore, the effectiveness of college education, as measured only by knowledge of student learning (Millett, Stickler, Payne & Dwyer, 2007), is not a sufficient evaluation. To increase accountability, more CTE programs may need to conduct follow-up studies with their graduates and the companies that employ them. Key stakeholders need to know that the program is relevant: professors want to know that their teaching is meaningful, administrators want to know that funding is justified, employers want to know where to find qualified employees, and prospective students want to know how their program of study will prepare them for the world of work (Feutz, 2010).

A quantitative design such as a follow-up survey describes the characteristics of the program and its graduates as a statement of the numerical value of one or more observable parameters (Glass & Hopkins, 1996). The extent to which graduates perceived they were prepared in areas of specific course material and the importance of that material to their job can also be measured. Similarly, a scaled survey is sometimes used to measure the extent to which employers believe graduate employees exhibit attributes of skill, knowledge, and attitudes. Such evaluations may be more common than is known through the literature, likely because institutions use the results for internal purposes. Although valuable, these data generally do not explain how course materials or graduates' attributes contributed to job success, nor could they explain what was useful about the material or attribute (Feutz, 2010). In contrast, a qualitative design answers "how" and "what" questions that allow exploration at a deeper level of understanding through inquiry (Creswell, 1998; Locke, Spirduso, & Silverman, 2007; Marshall & Rossman, 2006).

Qualitative Research

Many traditions or methodologies of qualitative inquiry exist; each one has unique features and characteristics for various types of study. Though many studies combine elements of two or more traditions (Creswell, 1998), this study most closely aligns with the characteristics of a phenomenology. A phenomenological approach is best employed in situations bounded by temporal and physical limits (Lancy, 1993), and it is used to study the lived experiences of several individuals to describe the "essence" of a phenomenon through the personal meanings of that experience from the subjects' perspectives (Bogdan & Biklen, 2003; Burke & Christensen, 2004; Creswell, 1998; Marshall & Rossman, 2006; Patton, 2002).

This study used a phenomenological design to gauge the alignment of the HVAC Engineering program with its industry, as measured by the perceptions of graduates. A phenomenology is used to study a specific experience shared by a relatively small number of people, purposefully chosen as a nonrepresentative sample (Bogdan & Biklen, 2003), using a systematic yet flexible in-depth interview structure based on open-ended questions (Bogdan & Biklen, 2003; Burke & Christensen, 2004; Creswell, 1998; Marshall & Rossman, 2006; Patton, 2002). The phenomenological method was chosen for this study because it offered opportunities to interact with subjects on a human-to-human basis, to explore further if necessary using follow-up questions, and to arrive at conclusions post hoc rather than a priori (Creswell, 1998; Lancy, 1993). Through this method, the research progresses inductively, with the researcher trying to make meaning out of the data. Preconceived notions or conclusions are not a part of qualitative inquiry, because they may cloud the researcher's findings (Bogdan & Biklen, 2003; Marshall & Rossman, 2006). Rather, the researcher attempts to remain as open-minded as possible, so that the meaning emerges from the data. Such a strategy allowed the exploration of the subjects' perception of the

HVAC program in great depth to determine the extent to which graduates were successful in the school to career transition. A qualitative assessment can bridge the gap between measures of school performance and job performance (Bragg & Hamm, 1996).

Research Questions

To comprehend the phenomenology of engineering graduates, the following research questions were employed:

1. What does the HVAC program mean to its graduates on a personal level?

2. How do graduates perceive they were prepared for their careers?

3. What are the essential core academic, general education, and nonacademic elements of a relevant HVAC program?

4. What changes, if any, could improve the HVAC program from the perspectives of pedagogy and relevance?

The answers to these questions reflect the perceptions of the graduates who participated in the study. These data provided a detailed portrayal of the strengths and weaknesses of the HVAC degree. Perhaps more important, the study brought to light what the degree means to graduates. These data supplied several measures of program quality and will be used as a basis for program improvement. The evaluation process may also be employed for other CTE programs.

Methods and Procedures

To recruit subjects for the study, contact information for all 110 HVAC graduates from the years 2007, 2008, and 2009 was solicited from the FSU administration. The size of the sample was relatively small, as is common in qualitative inquiry (Bogdan & Biklen, 2003; Creswell, 1998; Locke, Spirduso, & Silverman, 2007). The sample was also purposeful and involved only graduates from these three years. The reason for this delimitation was to interview those who were relatively new to the workforce. As time passes, it may be more difficult for graduates and employers to determine which knowledge and skills were learned in school and which were acquired through experience on the job. Therefore, subjects were not too far removed from their educational experience yet they have been in the workforce for a sufficient time to allow for reflection. The companies that employ the graduates vary by size, scope of work, geographic location, and geographic market.

After receiving approval from the university's human subjects review board, all potential subjects were invited to participate via an email message, and a second invitation was sent one week later to those who had not replied. A goal for the subject selection was that the experiences of both on-campus (n = 88) and online (n = 22) graduates would be represented; though the ratio of campus to online graduates is four to one, a similar sample size would have allowed for a comparison of themes between groups if that phenomenon arose. A total of 21 graduates (19%) responded to one of the two emails; 18 were successfully contacted and expressed willingness to participate. This sampling provided a diverse, nonrepresentative group. Because of the small number of program graduates, and the narrow focus of the study, the results are limited and should not be generalized to other populations or programs, although the evaluation process could be replicated widely.

The instrument of inquiry for this research was the open-ended, in-depth interview protocol, consisting of the four basic questions that were conducted over the phone due to the geographic separation among the subjects, and these were recorded to ensure accuracy. Qualitative interviews are conversational and exploratory, beginning with social conversations, and based on a few general topics (Moustakas, 1994). The subjects' responses were allowed to unfold in whatever form they wished to frame the discussion. The open-ended questions were designed to obtain data in a way that did not lead the subjects (Marshall & Rossman, 2006).

A total of 18 interviews were conducted. Ten of the subjects graduated from the traditional on-campus program and eight graduated from the online version, which presented an opportunity to analyze an additional variable. The two groups are highly differentiated by their age and years of experience (Figure 1); the on-campus participants were generally traditional college-age students, whereas the online students were typically aged 30s to 50s and already working in the field. Participants were asked to reflect on their educational and work experience and to explain how they felt they were prepared for their jobs. Follow-up questions were asked as

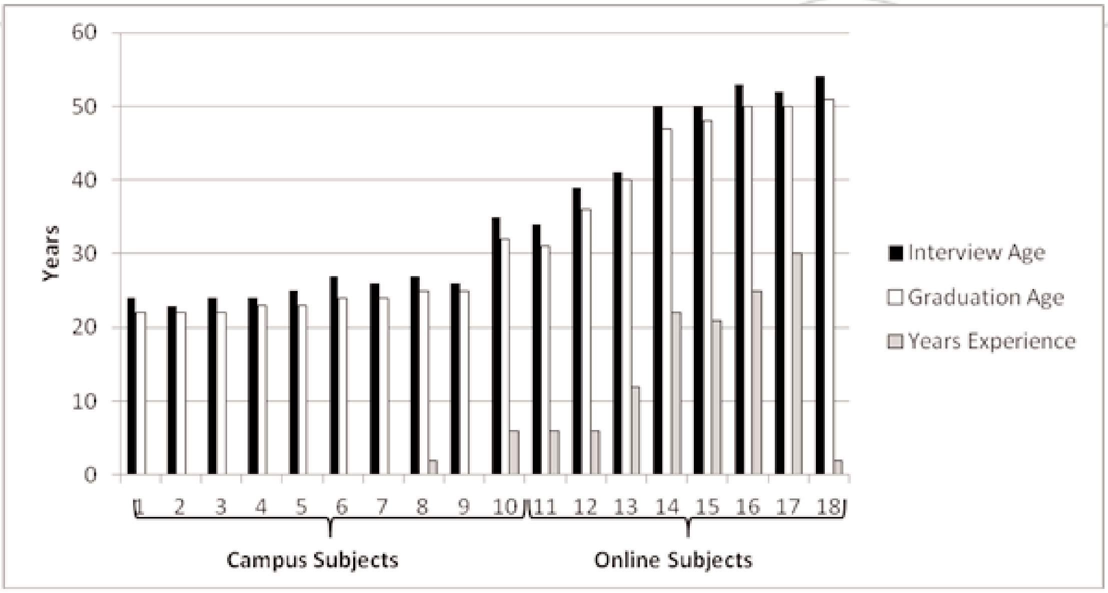

Figure 1. Subject Demographics

needed. Code numbers and pseudonyms were developed to provide anonymity. After the interviews, "member checking" was used to validate interpretations and descriptions of the experience. This involved asking interview subjects to review the transcripts in order to ensure that the experience was captured accurately from the perspective of the subjects and with minimum bias (Burke & Christensen, 2004). To organize the data, audio recordings of each telephone interview were transcribed; the data was coded via Excel through a process known as "phenomenological reduction" (Creswell, 1998). During phenomenological reduction, the researcher seeks to discover facts and themes that disseminate from the data; the researcher sets aside beliefs and knowledge of the phenomenon so that the true essence can be discovered from the perspective of the subjects. In all, 58 distinct headings were created to code the data. The headings were then clustered with other headings of similar meaning into six main themes that emerged in the study.

Findings

Based on the responses to the four research questions, six common themes (Figure 2) emerged for both campus-based graduates and online graduates. In general: (a) graduates think positively about the HVAC curriculum; (b) general education does not contribute significantly to the HVAC experience; (c) graduates find deep personal meaning in the HVAC experience; (d) assets and attributes of the program and the university contributed significantly to the positive experience of the graduates; (e) graduates are well-prepared for work; and (f) there is room for improvement. These themes are discussed in the following sections, which include a few highlights of how campus and online graduates differed. Pseudonyms are used whenever a subject's name appears.

Theme One: Strong Positive Attitude Toward HVAC

All subjects who graduated from the campus program chose the degree because it seemed to be a fit, piqued their interest, or allowed them to

1. Positive Attitude: *Focused curriculum *Challenging courses	**2. General Education:** *No direct value *Communication skills
3. Personal Meaning: *Gratitude *Self-fulfillment	**4. Quality Educational Assets:** *Supportive faculty *Student organizations
5. Graduates well prepared: *Work-based learning *Early responsibilities	**6. Suggested changes:** *Professional accreditation *Project management

Figure 2. Graduates' Thematic Perceptions

advance in their careers. Of the factors cited for making their decisions, subjects often spoke of the concentration on HVAC and the narrow focus of the program. Nick described how FSU helped him find a direction in school: Tony described how the program had given him an advantage over graduates of mechanical engineering programs that "just taught theories" and were "broad spectrum," whereas FSU was "very precise."

Though some subjects said they were good at it while in school, they also found the curriculum "challenging" or "difficult." At the same time, they saw the value in the challenge via the knowledge they gained. Subjects discussed the curriculum as a whole, but they also used individual courses to make their point from time to time, whether talking about their experience in school or on the job. The first course taken during the first semester of the HVAC program (HVAC 331 Secondary System Selection and Design) was described by some of the subjects as somewhat of a gateway course to the program. Where subjects saw HVAC 331 as a gateway to the degree, they saw the capstone course as culmination of their learning, and sometimes as their rite of passage. HVAC 499, as the capstone course, allows students to concentrate in an area of interest to them. Each year, students of the HVAC program submit their HVAC 499 capstone projects to be judged in an international student design competition. For John, HVAC 499 had the same effect. It focused the program, it had significant meaning for him, and it provided him with insight for his career.

Theme Two: General Education Courses

The investigators were interested in a holistic view of the HVAC degree. This included not only the core courses, but also the general education courses that are required for graduation. Overall, the responses were mixed. Unlike subjects who remembered specific HVAC courses and details within specific courses, these participants sometimes struggled to remember individual general education courses they had taken. Others mentioned a specific course that had meaning for them, or piqued a personal interest. Communication courses were most often cited as helpful. Josh said, "I guess you could say it helps you become a well-rounded person."

Theme Three: Personal Meanings--Pride, Gratitude, Self-Fulfillment

For the campus graduates, the strongest personal meaning was a feeling of pride in earning the degree. Although that feeling was not always explicitly stated, it was inherently obvious during the conversations, particularly when the subjects described their accomplishments on the job and their skills relative to coworkers who had earned their college degrees elsewhere. Josh, Brian, David, Brandon, Jordan, and Tony had all used coworkers or other graduates as a benchmark for their skill set. David had much stronger feelings and spoke at length about his gratitude, saying that the program and the faculty:

> have contributed to an excellent three years in the real-world and a great excellent four years in the college world as well . . . [It has] put me in many of the positions of success that I enjoy to this day, and I am very, very grateful . . . I do owe . . . a great deal of gratitude and thanks for the things that I get to enjoy in life now.

For others, the degree represented an opportunity to grow; it gave them a feeling of accomplishment and perhaps even self-fulfillment. Tony thought the experience "was pretty significant." He explained, "I felt that it was definitely a significant change that someone like me who is technical based, um, you know, struggles in English, struggles in just schooling in general that wasn't technical . . . I never thought that I would be able to do something like that."

Theme Four: Quality and Supportive FSU Educational Assets

"FSU assets" is a term to describe the characteristics of the experiences that had meaning for the subjects. The curriculum is a prime example of a characteristic. For many, either a favorite professor or the faculty in general were significant. Jack spoke both of his feelings for the faculty and of his perception of their attitude: "I liked every single teacher; they really did put a good effort into wanting you to learn the subjects." For Josh, the faculty members were included as factors in his personal growth: "The program and the teachers in the program really helped me become who I am today."

Second, several of the subjects discussed the social aspect of their campus experience, including personal interaction with faculty. Friendships were forged that had a meaningful impact on the lives of others. David's story is a perfect example. He actually landed his job based on information received from a friend. The third asset mentioned is the HVAC

Building, which was built in 2003 and designed with the mechanical, electrical, and plumbing systems exposed to enhance teaching and learning. The subjects involved in this research were among the first students to take courses in the new structure and the features of the building resonated with them. Many mentioned that the facility impressed them while visiting campus, and they enjoyed taking classes there for two years.

Another asset of the FSU program is the engineering student organizations; all but two campus subjects mentioned the organizations as significant. These student organizations provided opportunities for the subjects while they were on campus. In addition to campus activities, each organization hosts an annual conference, convention, or exposition at various locations throughout the United States. Students raise funds to attend or find sponsors to fund their travel expenses. Some of the organizations also sponsor student competitions, including the HVAC design competition that subjects spoke of on several occasions. Involvement in these organizations proved to be a significant element of many of the subjects' experience, particularly the opportunity to travel. Through the student organization sponsored trips, the subjects saw different parts of the country, developed their networks, and discovered new opportunities within the industry.

Theme Five: Well-Prepared Graduates

The overarching question for this study was: How do graduates perceive they were prepared for the industry as measured by what they know and know how to do as compared to what they need to know and be able to do? This theme answers that question, although it was often difficult if not impossible to extract and then separate salient points related to curriculum and work. Subjects used work examples to make their points when discussing the curriculum, and they used the curriculum to make their points when discussing their work.

Internship. The discussion began with the internship because, as both a required course and work experience, it illustrates the intricacy of the relationship between school and work in the HVAC program. As the first exposure to a full-time work experience for many subjects, the internship made the all-important connection between the world of school and the world of work, and, indeed, directly linked half of the campus subjects to full-time employment. Josh, Brian, Austin, Jack, and Tony parlayed the internship they served between junior and senior years into full-time employment upon completing their last year of school. A mock interview held during an advisory board meeting led to an official interview and subsequently a job for John. Many of the subjects spoke at length about the internship and their experiences. Comments from Josh's interview demonstrated how the internship provided the opportunity for an individual to "transition from an uncertain young college student to a confident young man ready to tackle the workforce."

During his internship, he gained experience with one manufacturer's controls in particular and learned controls using equipment from another manufacturer in the labs at FSU. Though neither company hired him, his portfolio documented his internship experience and helped him secure a job upon graduation with a third controls company. Since he "already knew two of our competitors' control systems," he found that the knowledge and experience gained through the internship and at school "helped out in certain scenarios." In hearing of the internships from the viewpoint of the subjects, it became evident that experiences were particularly significant to them. The internship seemed to be a transformational point in their lives, and as Josh articulated, "[he] grew up." It also gave them a chance to apply their knowledge and gave them confidence in what they knew and could do.

Another comparison between FSU graduates and other graduates was offered by Tony, who described how the limited expertise that he gained in HVAC 451: Energy Analysis and Audit led to considerable responsibilities for him on the job:

> I am the only person at [my company] that has done any energy modeling . . . we've got a full floor above me upstairs that is project engineers, project managers, and full-blown P.E.s [Professional Engineers] and they've never done energy and that is something that they really look to me . . . to help them . . . justify energy programs and energy projects and . . . retrofit opportunities.

Whereas conducting energy auditing has simply been added to the responsibilities of both Tony and John, David actually carries the title of Energy Engineer. This is a position he secured because of the knowledge he gained through the HVAC program and HVAC 451 in particular. David's description of his duties read like the 451 course description.

Deep End of the Pool. Many subjects found themselves with significant responsibilities soon after beginning their job. Most often, though not always, this was a confidence builder for the subjects. For Tony, as the only employee at his firm capable of performing energy audits, the knowledge that he acquired in HVAC 451 amounted to a double-edged sword. Out of school only one year, the responsibilities that he had gained were a bit intimidating, yet through his knowledge, limited though it was, he gained the trust of his superiors and colleagues.

Theme Six: HVAC Is Not Perfect

Asking, "What would you change about the program?" enabled the interviews to take on a richer and more in-depth narrative describing the experiences of each subject. Two topics came to the surface: the lack of professional accreditation and the need for a business-related course. In brief, the HVAC program is not accredited by the Accreditation Board for Engineering and Technology. This was a conscious decision by FSU to provide a more narrow industry focus rather than the broader mechanical engineering program. However, this choice prevents graduates from becoming licensed or registered as professional engineers (P.E.s). HVAC graduates can do everything a P.E. can, but they lack the authority to sign or "stamp" engineering documents and take legal responsibility for them.

The second main subtheme to appear under opportunities for improvement was the addition of a course, or at least learning objectives, related to the business side of the industry. Representing the perspective of other subjects, Tony felt that he was not prepared for the "whole management of time and people and resources. I felt like I wasn't really prepared enough." Along the same line of thought, Brandon said, "one of the things I felt was a weak point is just learning about the different parts of a job . . . how the whole bid process works and how a job evolves."

The Online-Degreed Graduates

All of the online graduates who participated in this study chose the online option for its convenience. All were employed while earning their degrees, and with all but one living outside of the state, they were able to continue working and living at home. For the online subjects, the curriculum varied in meaning from the campus subjects. Though they certainly felt it was a "real-world" experience as the campus subjects did, they also found it to be enlightening. Because they already had extensive industry knowledge, some found there was much more to know and learn. Others found portions of the curriculum to be familiar territory, thus validating the work they had been performing during their careers. With his extensive field experience, Nathan found the HVAC program to be enlightening. While in the field, he had known enough to "make the stuff work" but he did not always understand why (which seems to be the reverse of campus students). Online students also spoke about the capstone project and its real-world application. Josh said: ". . . and the situation that you run into in real life is there may be more than one solution to a problem and it's up to you to decide which solution you want to use to best help that customer. And it's not textbook, although you do use textbooks to come to a solution if you have questions about a particular situation."

For the online subjects, interaction with faculty was limited to electronic or phone communications, with one exception. As students, they started in the fall of their enrollment year with the first HVAC course. During the winter semester they took the second HVAC course, followed by the third during the summer. In August of that first summer, they all traveled to campus for a five-day hands-on laboratory learning experience. During this time they met each other, their professors, and their advisor for the first (and only) time. Several graduates commented that faculty members were highly regarded in the industry, and it was rewarding to meet them in person.

Many of the social aspects of college can be lost in the online format, particularly when the students are scattered across the country as they are in the HVAC online program. Yet the subjects managed to find social interaction with fellow students and with the faculty and staff of the university and established meaningful relationships in the process. John related that "as I went on [in the program] I got introduced to students that were online and we formed a network where we could discuss things with people from different parts of the country."

To enhance online learning, faculty recorded and edited their lectures and provided students with CDs containing all the lectures and other materials that were needed to supplement written materials. Faculty members were pleased to hear that students believed the CDs were effective tools. As Tyler noted:

> I think CDs are the way to go because the student can get out of school and he can refer back to those CDs for years . . . I thought that was excellent . . . that is very important. I'm the type person that when I go to a class, especially one that is important in my field, I keep all that data and I categorize it and put it in notebooks or crates. And that way I can refer back to it over and over as I have in the past.

Other subthemes emerged when subjects were asked what they would change about the HVAC program. Online graduates noted that some of the materials they received either contained errors or were outdated. There was a delay in communication associated with online learning. Subjects cited specific courses where feedback from their professor was delayed by up to a month. One subject expressed the feeling they were "drifting for several weeks at a time." Even with the normal communication lag expected when using electronic communication in the form of email, when faculty schedules did not align with student schedules, the students had no way to ask a question and get an instant response unless they happened to be in a live chat room. Because they had full-time jobs, subjects found themselves working on their courses during the nights and weekends, which were often the times when faculty were not at their computers. Greg did not comment on communication issues, but he did complain that general education courses were difficult for online students to take because of the limited offerings. He acknowledged that FSU had added more courses as time went on, but for him, many of those courses came too late and he struggled to find the general education courses that he was required to take.

Review of differences. To summarize the comparisons between the two groups of graduates, several facts differentiated online subjects from the campus subjects relative to the world of work. First, for the campus subjects, their internships were significant features of their HVAC experience. The internships led to full-time employment, provided the connection between school and work, and helped the students mature. The online subjects did not serve internships. Though the internship was required of them, their HVAC-related job experiences allowed them to earn their internship credits though a proficiency-by-portfolio process. Also, because they had an average of 15.5 years of work experience, the internship would not have provided the same meaningful introduction to the world of work as it had for the campus subjects.

Second, while the campus subjects felt they entered the job market at the "deep end of the pool," the online graduates had already been in the "pool" for years, so while this was a significant experience for the campus subjects, it was not a factor for the online subjects. Third, the campus subjects measured themselves against their coworkers who had graduated from other institutions, and often with a degree in mechanical engineering. The campus subjects believed they were better prepared than their counterparts. That experience did not emerge with the online subjects, as they were seasoned veterans with significant expertise even before they earned their HVAC degree; thus, there was no need for them to find a benchmark against which they could measure themselves. Finally, some of the online students needed the baccalaureate degree to either secure their job or to be eligible for promotion within the same company. Like some others, Steve did not need a baccalaureate degree for employment or promotion purposes, having progressed far into his careers with only an associate degree, but he wanted a baccalaureate for reasons of personal fulfillment.

Discussion

This phenomenological study served as a tool for program analysis and improvement. When asked about their experiences, the subjects defined their personal meanings using specific elements of the program. When viewed from the perspectives of its graduates, the strengths and weaknesses of the program became apparent, and two critical elements of its invariant structure emerged. First, the program aligned sufficiently well with students' needs and interests in a technical degree to be described as a good fit for them. Second, the data revealed that the curriculum aligned precisely with the sectors of industry for which it was designed. Because of these alignments, graduates perceived the program as the premier educational experience in their field and exhibited feelings of great personal pride and a sense of accomplishment due to their affiliation with and graduation from it.

With the long history of CTE as workforce development or education for jobs, and federal legislation to regulate that education, this study reinforces the importance of a curriculum that is aligned with the industry for which it prepares its students, and it provides strong evidence that a unique CTE program can and does have a role in the current educational system. The strong feelings of the participants that the HVAC program fit their needs, provided excellent preparation for their careers, and fostered a strong sense of job security seem to highlight the merit in narrowly focused CTE curricula.

From the perspective of credibility, though the public perceives CTE as something less than academic (Cohen & Besharov, 2002), the pride and success projected by the participants of this study indicate just the opposite. This carries the implication that quality CTE programs can have as high a value as academic programs. It follows that efforts to increase the quality across the spectrum of CTE could improve its perception in the public eye. In addition, publishing and promoting the results of effective programs can help demonstrate their significance. An important distinction must be pointed out: the HVAC program is a baccalaureate-level degree. This is an anomaly within CTE, as the vast majority of programs exist at the secondary or associate degree level. Perhaps this study makes an argument for elevating more CTE programs to the baccalaureate level.

Though existing quantitative data had indicated a high level of quality in the HVAC program, this qualitative study provided answers to "how" and "why" questions and identified areas of strength and areas of weaknesses in which quality improvements could be made. In fact, the study would still be valuable to the college even if the results were more negative. To further the research, perhaps the qualitative findings from this small sample could be used to develop a quantitative survey instrument for administration to a larger sample to provide results that would be more generalizable, so that the evaluation process could be replicated for other CTE programs.

Michael Feutz teaches Heating, Ventilation, Air Conditioning and Refrigeration Engineering Technology at Ferris State University, Big Rapids, Michigan.

Dr. Richard Zinser is a teacher-educator in vocational education at Western Michigan University, Kalamazoo.

References

Barlow, M. L. (1976). History of CTE. American Vocational Journal. Retrieved from http://www.acteonline.org/ctehistory.aspx?terms=history.

Bogdan, R. C., & Biklen, S. K. (2003). *Qualitative research for education: An introduction to theory and methods* (4th ed.). Boston, MA: Allyn and Bacon.

Bozick, R., & Macallum, K. (2002). *Does participation in school-to-career limit students' educational and career opportunities? Findings from the LAMP Longitudinal Study.* Academy for Educational Development, Washington D.C. Retrieved from http://www.eric.ed.gov./ (ED475123)

Bragg, D., & Russell, E. (1993). *Linking college and work: Exemplary policies and practices of two-year college work-based learning programs.* National Center for Research in Vocational Education, Berkeley, CA. Retrieved from http://www.eric.ed.gov./ (ED396155).

Bragg, D. D., & Hamm, R. (1996). *Linking college and work: Exemplary policies and practices of two-year college work-based learning programs (MDS-795).* Berkeley: National Center for Research in Vocational Education, University of California at Berkeley. Retrieved from http://www.eric.ed.gov./ (ED396115).

Brown, J., & Conbere, J. (2005). *A quantitative case study focused on using a human resource development system to analyze the program performance assessment strategies of federally funded career and technical education programs in 12 Minnesota technical colleges.* Online Submission; Paper presented at the Academy of Human Resource Development International Conference (AHRD) (Estes Park, CO, Feb 24-27, 2005) pp. 1132-1137 (Symp. 49-2). Retrieved from http://www.eric.ed.gov./ (ED492277)

Burke, J., & Christensen, L. (2004). *Educational research: Quantitative, qualitative, and mixed approaches.* Boston, MA: Pearson Education.

Cohen, M., & Besharov, D. (2002). *The role of career and technical education: Implications for the Federal Government.* Paper commissioned for "Preparing America's Future: The High School Symposium" (Washington, DC, April 4, 2002). Retrieved from http://www.eric.ed.gov./ (ED466939).

Coryn, C, L., Gullickson, A. R., & Hanssen, C. (2004). *Assessing the impact and effectiveness of the Advanced Technological Education (ATE) Program.* Kalamazoo, MI: The Evaluation Center, Western Michigan University. Retrieved from http://www.wmich.edu/evalctr/ate/publications

Creswell, J. (1998). *Qualitative inquiry and research design: Choosing among five traditions* (1st ed.). Thousand Oaks, CA: Sage.

Feutz, M. (2010). *The Phenomenology of the Bachelor of Science in HVAC Engineering Technology from Ferris State University.* (Unpublished doctoral dissertation). Western Michigan University, Kalamazoo, Michigan.

Glass, G. V., & Hopkins, K. D. (1996). *Statistical methods in education and psychology* (3rd ed.). Needham Heights, MA: Allyn & Bacon.

Kagaari, J. R. K. (2007). Evaluation of the effects of vocational choice and practical training on students' employability. *Journal of European Industrial Training. 31*(6), 449-471.

Kirkpatrick, D. (1994). *Evaluating training programs: The four levels.* San Francisco: Berrett-Koehler Publishers.

Knox, A. (1998). *Evaluating adult and continuing education.* Columbus, OH: ERIC Clearinghouse on Adult, Career, and Vocational Education.

Lancy, D. F. (1993). *Qualitative research in education: An introduction to the major traditions.* White Plains, NY: Longman.

Locke, L. F., Spirduso, W. W., & Silverman, S. J. (2007). *Proposals that work* (5th ed.). Thousand Oaks, CA: Sage.

Marshall, C., & Rossman, G. B. (2006). *Designing qualitative research.* (4th ed.). Thousand Oaks, CA: Sage.

Millett, C. M., Payne, D. G., Dwyer, C. A., Stickler, L. M., & Alexiou, J. J. (2008). A culture of evidence: An evidence-centered approach to accountability for student learning outcomes. *Educational Testing Service.* Retrieved from http://www.acteonline.org/uploadedFiles/About_CTE/files/EvidenceCenteredAToAcc.pdf

Millett, C. M., Stickler, L. M., Payne, D. G., & Dwyer, C. A. (2007). A culture of evidence: Critical features of assessments for postsecondary student learning. *Educational Testing Service.* Retrieved from http://www.acteonline.org/uploadedFiles/About_CTE/files/CriticalFAPSecSL.pdf

Moustakas, C. (1994). *Phenomenological research methods.* Thousand Oaks, CA: Sage.

Patton, M. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Rahn, M. L., O'Driscoll, P. & Hudecki, P. (1999). Taking off! Sharing state-level accountability strategies using academic and vocational accountability strategies to improve student achievement. *NCRVE Materials Distribution Service.* Retrieved from http://www.eric.ed.gov./ (ED431138)

Zinser, R. (2003). Evaluation of a community college technical program by local industry. *Journal of Industrial Teacher Education. 40*(2), 51-64.

Zinser, R. (2012). The evaluation of technical education programs. Manuscript submitted for publication.

The Impact of In-Service Technology Training Programmers on Technology Teachers

Mishack Gumbo, Moses Makgato, and Heléne Müller

Abstract

The aim of this paper is to assess the impact the Advanced Certificate in Education (ACE) in-service technology training program has on technology teachers' knowledge and understanding of technology. The training of technology teachers is an initiative toward teachers' professional development within the mathematics, science, and technology sphere of education (MSTE). ACE is a two-year training program that technology teachers in the Gauteng and Mpumalanga Provinces (South Africa) attended during 2008 through 2009. The program attendees were senior phase teachers, of whom a few taught in the Further Education and Training band of education (certain high schools begin with grade 8). The research problem that the study addressed is stated in terms of the following hypothesis: There is no statistically significant difference between the pre- and post-knowledge and understanding survey scores for teachers attending the ACE professional development program in technology education. A survey questionnaire to collect biographical and technological input was administered to teachers who attended on the days the questionnaire was administered. The same questionnaire was administered at the beginning of training in 2008 and at completion of the program in 2009. The aim of the quantitative study was to evaluate whether the ACE-Technology training had a statistically significant impact on technology teachers' knowledge and understanding of technology. In total, 304 completed questionnaire responses were included in the study. The results indicated that there were improvements in the teachers' technological knowledge and understanding. This indicates that teachers benefited positively from the ACE-Technology training.

Keywords: Advanced Certificate in Education, in-service training, technology teachers, technology teaching capabilities, professional development programs, MSTE education, nonparametric Kruskal-Wallis test, Wilcoxon test.

Background Of The Study

The introduction of outcomes-based education (OBE) in the form of Curriculum 2005 (C2005) was a huge educational reform in the history of South Africa. C2005 was reviewed twice and became consecutively known as the Revised National Curriculum Statement (RNCS), the National Curriculum Statement (NCS); currently it is the Curriculum and Assessment Policy Statement (CAPS). It is envisaged that CAPS will be implemented in 2012 (Department of Education [DoE], 2005, 2010). The reviewed versions have not lost their OBE flavor per se, as the present version is still undergirded by the curriculum principles rooted in the South African *Constitution's* "Preamble," which motivated the transformative OBE curriculum approach (DoE, 2003, 2010).

The OBE approach to the curriculum created a gap between the requirements of the OBE and training the majority of teachers previously received (Ono & Ferreira, 2010). Because the pedagogic practice of the OBE differs from previous practice, intensive, continuous professional teacher development is imperative to prepare teachers for the implementation of the revised curriculum. The urgency of the matter becomes even more apparent considering the training of underqualified and unqualified teachers is still incomplete and a reality to be dealt with (Jansen & Christie, 1999; Taylor & Vinjevold, 1999). Although the qualifications of many teachers in the country have improved, the majority of teachers have not been sufficiently equipped to meet the changing educational needs of modern society (DoE, 2006). Two of the most important factors in determining whether teachers are adequately equipped to teach technology successfully are content knowledge (subject matter) and pedagogic skills (Aluko, 2009). Most studies in teacher development have found that many teachers seriously lack pedagogic skills regarding supporting individual differences in students (Kent, 2004; Laine & Otto, 2000). Insufficient pedagogical skills may be attributed to current teacher education and development practices for both pre-service and in-service teachers (Kent, 2004).

The previous literature references emphasize that continuous professional development is crucial for teachers who work in an environment of school curriculum changes. Adequate time should be made available for teachers to study and plan if they are to effectively and successfully implement the curriculum (Laine & Otto, 2000). Literature indicates that most school districts in America usually provided too little time for professional development (Kent, 2004). The outcome of such a situation is that teachers may not be in a position to pass sound judgment regarding learners' needs.

The research described in this article is approached from the perspective of a teacher's professional development. According to Villegas-Reimers (2003, p. 11), professional development is broadly defined as "the development of a person in his or her professional role." More specifically, teacher development is explained as "the professional growth which a teacher achieves as a result of gaining increased experience and examining his or her own teaching systematically" (Gatthorn in Villegas-Reimers, 2003, p. 11). According to Villegas-Reimers (2003), professional development includes formal experiences such as reading professional publications, watching TV documentaries related to an academic discipline, and attending cluster meeting workshops. It is broader than career development, staff development, or in-service training, and it includes a long-term development process.

Teacher training is pivotal to the success of curriculum change (Brown, Sithole, & Hofmeyr, 2000). Thus, the challenge to the system is to help teachers to become change agents and thereby enable them to lend impetus to transformation (Brown et al., 2000; DoE, 2006) through creative approaches (Castellano & Datnow, 2000; Kent, 2004). Many studies have shown that teacher competence in pedagogic and content knowledge is crucial for student achievement (Borko, Elliott, McIver, & Wolf, 2000; Darling-Hammond, 2000; Kent, 2004; Pikulski, 2000; Rivers & Sanders, 1996). In an attempt to develop teachers professionally, the DoE in South Africa proposed new professional qualifications for teachers, namely the four-year Bachelor of Education (BEd) degree, with a senior certificate, that is matric plus four years' qualification as prerequisite; and a Postgraduate Certificate in Education (PGCE) (Aluko, 2009). However, in reality in South Africa about 40% of practicing teachers are either unqualified or underqualified (DoE, 2009) and hold outdated teachers' diplomas, such as the Primary Teachers Diploma, the Senior Primary Diploma in Teaching, the Junior Primary Teachers Diploma, or the Senior Teachers Diploma (Welch, 2009). According to a survey undertaken by the Human Science Research Council (HSRC), only about 18% of currently practicing teachers are professionally qualified.

Technology Learning Area (TLA) and Teacher Development

The introduction of technology education has triggered an urgent and fervent need for in-service technology teacher training as part of teachers' professional development. This need was exacerbated by the fact that technology education was introduced as a relative newcomer at the inception of C2005 (Gumbo, 2003; Maluleka, Wilkinson, & Gumbo, 2006). There were no trained or qualified technology teachers at this stage. When technology education was rolled out with C2005 in 1998, teachers, qualified in other subject fields, were asked by the DoE to volunteer to teach technology. They thus started teaching technology with a very limited pedagogical content knowledge background. Similar developments were reported internationally. Reference can be made to China, where teachers "floor-crossed" from other disciplines – with different knowledge backgrounds – into technology education (Feng & Siu, 2009). Feng and Siu (2009) view in-service teacher education, based on the China experience, as a crucial factor in technology curriculum development.

As part of a formal two-year qualification to address the technology teacher training backlog, the DoE decided on the ACE qualification to fast-track teacher training, particularly as an in-service training course. The ACE program enables teachers to upgrade from a Matric + 3 (matric plus three years' qualification) to an M + 4. The ACE furthermore provides the option for practicing teachers to either qualify in a new subject learning area or to specialize in a subject/learning area that they are currently teaching (DoE, 2000). The admission requirements for entry into the ACE program include professional qualification. This qualification may be either a three-year teachers' diploma, or a BEd degree (Aluko, 2009). When the program it completed, it is envisaged that teachers will be highly competent in terms of knowledge, skills, and didactics relevant to the subject. This is in keeping with the principles of the National Policy Framework for Teacher Education and Development in South Africa, which states that "a teacher should be a specialist in a particular learning area, subject or phase" (DoE, 2006, p. 5).

Since 2002, in-service training workshops sponsored by the DoE for Higher Education Institutions have been held for teachers during school holidays and on Saturdays. In this regard, Potgieter (2004) accounted for some 137 teachers who participated in workshops that he facilitated, and some 950 teachers who enrolled with the University of South Africa in 2002 for the ACE program. However, despite these initiatives, according to Ndahi and Ritz (2003), the supply of technology teachers is still minimal and should continue to receive attention. The DoE (2006, p. 16) furthermore stated that "both conceptual and content knowledge and pedagogical knowledge are necessary for effective teaching."

The nature of technology is more of project based and problem driven. This means that students design and make projects to solve identified problems with "structures," that is, electrical and mechanical systems. In line with this nature of technology, the ACE training program reported in this article covered the following topics: (1) technological processes and skills, which includes investigate, design, make, evaluate, and communicate. It is about designing, making, and evaluating technology prototypes or artifacts to solve technological problems while incorporating a range of other technological processes; (2) technological concepts and content knowledge, which includes structures, material processing, electrical/electronic control systems, and mechanical systems; (3) indigenous technology, which is about the impact and biases that technology has on society and the environment. These topics were integrated in the practicals that teachers conducted within "structures," electrical and mechanical systems.

Limitations

The research under discussion was designed as an exploratory study, and a quantitative research approach was used to this effect. A mixed-model approach, in which quantitative results (e.g., interviews) complement quantitative deductions, could have enriched the findings. Time and funding was however a restricting factor in this study; therefore, it was argued that once the impact of technology training had been verified, future studies should incorporate additional aspects, such as the length of the training presented, countrywide representation of respondents, and qualitative methods to strengthen research findings.

Research Design

The formal hypothesis of the research question on the impact that the Technology- ACE training program has on technology teaching knowledge of practicing teachers can be formulated as follows: There is no statistically significant difference between the pre- and post-knowledge and understanding survey scores of practicing teachers who completed the ACE professional development program in technology education. The research environment in which the research was conducted that is reported on in this article is briefly discussed in this section.

The first two authors were involved as facilitators in an ACE-Technology training program offered during 2008 and 2009. The program was a collaborative project between the Tswane University of Technology and the Vaal-Triangle University of Technology, and it trained senior phase technology teachers of the Gauteng (Sebokeng, Johannesburg North, Soweto and Tswane West Districts) and Mpumalanga Provinces (Bushbuckridge District). The authors were keen to assess the impact of subject-specific (technology education/TLA) training on technology teachers' knowledge and understanding of the subject of technology education. Hence, the researchers integrated their training with the research project under discussion and undertook a quantitative survey design study.

A questionnaire was designed and administered to technology teachers at the beginning of the ACE-Technology training program in 2008 to determine the status of teachers' technological knowledge and understanding. The same questionnaire was administered to the same teachers when they completed the program in 2009 to determine the impact that the training had had on the teachers' perceptions of their technological knowledge and understanding. The questionnaire included 14 questionnaire statements on teachers' perception of their knowledge and understanding of technology education subject matter and interpretation (see Tables 2 and 3). The statements were scored according to a five-point Likert agreement rating scale. Questions on biographical attributes included training background, qualifications, and qualifying institutions, as well as present and past teaching experience.

Ethical research aspects were addressed by acquiring permission to conduct the research from the DoE and participating parties. ACE organizing officials and senior DoE staff who visited the training sites were approached for ethical clearance. Survey participation was voluntary, and the purpose of the study was explained to the participating teachers.

The target population of the study was practicing technology teachers and the population was sampled purposively since several logistical problems initially compromised random sampling: teachers interpreted the registration procedure incorrectly due to poor communication by the DoE; and other teachers enrolled late because school managements granted permission at a late stage; in other cases teachers attended classes infrequently; or teachers who had been selected to attend did not attend and some teachers switched between the ACE specialization fields of mathematics, science, and technology. As a result, 304 teachers who were conveniently available participated in the questionnaire survey.

Analysis Strategy

One-way frequency distributions on respondents' biographical attributes were calculated to provide a descriptive background of the sampled population and to verify the representativeness of the sample in terms of target population attributes. These frequency distributions were furthermore used to determine whether biographical attributes could be further investigated for their effect on teachers' technology knowledge acquisition – over and above the effect that the ACE-Technology education training program had on the acquisition and understanding of technology knowledge.

Composite frequency tables on the knowledge and understanding perception rating statements (14 statements), which respondents rated before and after the completing the ACE- Technology education training were also calculated to provide a general overview of respondents' perceived knowledge and understanding prior to and after the ACE training (Table 2). The difference between pre- and post-ACE technology knowledge and understanding perception scores were also calculated for each respondent and statement. The analysis strategy argued that if training did not affect the perception of teachers' technological knowledge and understanding, perception ratings prior to and after ACE-Technology training would be more or less the same. This no-effect assumption would imply that the difference between pre- and post-training scores would be close to zero. A nonparametric Wilcoxon- signed rank test was conducted on all difference ratings, combined over all the questionnaire statements, to test the hypothesis that the general mean difference rating score was zero. Separate tests were also calculated on the 14 sets of difference scores for each knowledge statement. These tests were conducted separately to assess whether teachers perceived to have significantly improved their knowledge and understanding on each aspect of technology tutoring that the questionnaire probed.

Once the issue of the impact of ACE-Technology training had been validated, the analysis strategy investigated the effect that biographical attributes – such as previous technology tutoring experience and previous technology training, could possibly have had on the expected increase in technology knowledge and understanding (over and above the effect of ACE-Technology training on technology knowledge and understanding). Nonparametric analysis of variance (Kruskal-Wallis one-way analysis of variance) was used to investigate this aspect of the research. The analysis strategy was duly followed and analysis results are presented in the next section.

Analysis Results and Interpretation

Biographical attributes of the sample

Table 1 presents the frequency distributions of the biographical variables probed in the questionnaire.

These distributions describe the sample as teachers of whom approximately the same proportion was selected/or attended the ACE technology education program voluntarily (50.34% and 48.65%); and the same proportion had no/had previous formal training in technology teaching (58.75% and 41.25%). The figures show that previous training was most commonly gained from week-long workshops (51%) and that previously acquired technology education qualifications mostly consisted of an attendance certificate (58.14%). Approximately half of the respondents had taught technology previously, and 73% of teachers were currently teaching technology.

Table 1
One-way frequency distributions of respondents' biographical attributes

How were you selected? (missing = 8)					Qualifying institution (missing = 217)				
	f_i	%	Cum f_i	Cum. %		f_i	%	Cum f_i	Cum. %
DoE inst. urban	92	31.08	92	31.08	Secondary Sch	13	14.94	13	14.94
School sent me	57	19.26	149	50.34	Tech/College	17	19.54	30	34.48
I volunteered	144	48.65	293	98.99	University	31	35.63	61	70.11
Other	3	1.01	296	100.00	In- job training	22	25.29	83	95.40
					Private Inst	4	4.60	87	100.00
Training background in Technology education? (missing = 1					Taught technology prior to ACE? (missing = 5)				
Yes	125	41.25	125	41.25	Yes	160	53.51	160	53.51
No	178	58.75	303	100.00	No	139	46.49	299	100.00
Type of training (missing 171)					Grade taught previously (missing 226)				
Workshop	105	78.95	105	78.95	Grade 8	78	100.0	78	100.00
Tech Ed qual.	22	16.54	127	95.49					
Other	6	4.51	133	100.00					
Workshop duration (missing = 187)					Currently teaching technology (missing = 4)				
One day	32	27.35	32	27.35	Yes	219	73.00	219	73.00
Two days	14	11.97	46	39.32	No	81	27.00	300	100.00
Three days	11	9.40	57	48.72					
One week/more	60	51.28	117	100.00					
Type of qualification (missing = 218)					Grade currently teaching (missing = 216)				
Attendance cert.	50	58.14	50	58.14	Grade 8	86	97.73	86	97.73
Diploma	28	32.56	78	90.70	Grade 12	2	2.27	88	100.00
1st Degree	6	6.98	84	97.67					
H/ M/ Doctorate	2	2.33	86	100.00					

The deduction could thus be made that the sample appropriately represented the target population of the research, namely, practicing technology teachers with limited formal teaching qualification.

Once the adequacy of the sample had been verified, the authors' attention was turned first to an exploratory overview of technology knowledge and understanding perception trends and next to a formal validation of these observed improvement trends. A summary of the respective analysis results is presented in Tables 2 and 3.

Perceptions regarding technology knowledge and understanding

In Table 2, the total frequency distribution row before onset of the ACE program indicates that the majority of perception responses fell in the *no-experience to limited experience* categories (61%). If the perception rating scale of no experience to extensive experience is interpreted as *"a substantial lack of knowledge"* to *"substantial knowledge or confidence,"* then the deduction can be made that respondents seemed to lack the general academic knowledge and understanding to teach technology before they started the program.

On the other hand, when the participants completed the program the total row frequency distribution indicates that respondents in general felt more relaxed about their academic knowledge and understanding of technology once they had undergone ACE- Technology training, since the majority of responses now fell in the *moderate* to the *more than average* experience perception categories (91%). This shift seems to indicate that respondents felt more confident about their technology knowledge and insight once the ACE-Technology training program had been completed.

Table 2
Frequency distributions of 304 participants to the 14 knowledge and insight perception rating statements of the technology survey questionnaire scored prior to and on completion of the ACE-Technology training program

	No experience		Limited experience		Moderate experience		Above average experience		Extensive experience		Totals	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1. Meaning of technology	64	3	108	10	87	143	38	134	6	6	303	296
2. Meaning of tech. Education	86	3	108	12	72	140	31	133	3	6	300	294
3. Learning outcomes, ass. stds	89	3	68	11	83	101	58	172	3	7	301	294
4. Grasp/apply design process	106	4	71	9	76	125	46	152	5	6	304	296
5. Identify problems/ needs/wants	87	3	94	16	74	132	39	137	3	2	297	290
6. Structures/strengthening techniques	77	3	77	11	84	122	51	153	3	5	292	294
7. Priorities, selecting materials	75	3	100	16	78	119	46	152	2	3	301	293
8. Systems and control	90	5	99	26	72	144	27	112	0	4	288	291
9. Design, completing projects	96	4	88	22	84	148	28	116	3	4	299	294
10. Identify and apply resources	78	3	90	21	91	132	34	134	2	3	295	293
11. Tech. lesson planning	87	3	91	21	88	137	30	127	1	4	297	292
12. Tech. methods and strategies	97	5	103	20	66	151	32	114	1	4	299	294
13. Tech. assessment	104	5	96	26	71	154	27	106	1	3	299	294
14. Implement NCS Tech Grade 8	99	4	92	27	77	146	31	114	2	1	301	292
TOTAL	1235	51	1285	248	1103	1894	518	1856	35	58	4176	4107
Percentage of pre-/post-totals	30%	1.4%	31%	6%	26%	46%	13%	45%	.1%	1.6%		
Frequency Missing = 80 (pre); 149 (post)												

Table 3
Wilcoxon signed-rank test results on the overall pre- post-difference dataset and on the fourteen subsets of pre-post-differences for each of the questionnaire statements to test the hypotheses, of location: $Mu_0 = 0$

Signed-rank test to test the null hypothesis of no overall improvement in knowledge once ACE-technology training is completed *($H_0 : Mu_0 = 0$)*

Knowledge aspect	*N*	S-statistic Signed-rank test	Probability associated *S*-Statistic	Mean (std. dev.)	Skew -ness	Kurtosis
Signed rank test to test the null hypothesis of no overall improvement in knowledge once ACE-technology training is completed *($H_0 : Mu_0 = 0$)*						
Overall knowledge improvement[#]	4047	2195144.00	< 0.0001***	1.19 (1.00)	0.05	-0.63
The signed rank sum test results on knowledge statements (14) assessed in the questionnaire						
Meaning of technology	296	11420.00	< 0.0001***	1.08 (0.93)	0.14	-0.29
Meaning of technology education	290	12472.00	< 0.0001***	1.27 (0.98)	-0.10	-0.48
Learning outcome, assessment standards	291	9401.00	< 0.0001***	1.21 (1.12)	0.12	-0.55
Grasp and apply design process	296	11301.50	< 0.0001***	1.28 (1.12)	-0.01	-0.86
Identify problems, needs and wants	287	11218.00	< 0.0001***	1.20 (1.01)	-0.01	-0.78
Structures, strengthening techniques	283	10027.50	< 0.0001***	1.14 (1.00)	0.05	-0.84
Priorities, selecting material	291	11038.50	< 0.0001***	1.17 (1.02)	0.11	-0.80
Systems and control	278	11542.50	< 0.0001***	1.19 (0.90)	0.13	-0.54
Design, completion of projects	290	10953.00	< 0.0001***	1.18 (0.99)	0.01	-0.62
Identify and apply resources	286	11065.50	< 0.0001***	1.13 (0.94)	0.06	-0.65
Lesson planning, technology	287	11385.00	< 0.0001***	1.18 (0.99)	0.14	-0.68
Technology methods and strategies	290	11489.50	< 0.0001***	1.22 (1.00)	-0.03	-0.60
Implementation tech assessment	291	12501.50	< 0.0001***	1.22 (0.95)	-0.05	-0.64
Grasp, implement Grd R9 NCS Tech	291	11863.50	< 0.0001***	1.15 (0.97)	-0.01	-0.59

#: The differences for the overall knowledge improvement variable were calculated by subtracting scores rated on program completion from ratings scores rated prior to course commencement for each of the 14 subquestions for each respondent. The total number of responses considered was therefore 14 x 304 = 4256.

For the individual rank tests only data of respondents that completed the same question on both questionnaires could be included in the various analyses, therefore varying totals are reported.

Nonparametric Wilcoxon Signed-Rank Tests

These initial indications of technology competency shifts were further explored and statistically validated by means of nonparametric Wilxocon signed-rank tests. The tests were conducted on the combined difference data set as well as on the 14 individual subsets of pre- post-difference scores for each of the 14 questionnaire statements for all respondents. The null hypotheses evaluated in all instances state that the ACE program did not statistically significantly improve technology competencies in any respect (14 competency aspects and a general trend), as opposed to the alternative hypotheses of a statistically significant effect of ACE-Technology intervention on technology competency. Table 3 summarizes the results of the Wilxocon tests.

Highly significant Chi-square test statistics were associated with all Wilcoxon signed- rank tests (column 4 Table 3). The tests therefore verify initial indications of positive shifts in perceived technology competency. The general test in Table 3 verified that teachers perceived ACE-Technology programs to statistically significantly improve their technology teaching competencies; more specifically, teachers perceived that all (14) aspects of their t echnology knowledge and understanding that were probed in the questionnaire were statistically significantly enriched by the ACE-Technology intervention.

Nonparametric Kruskal-Wallis Analysis of Variance

The results, derived from Tables 2 and 3, thus answered the main concern of the study: ACE-Technology intervention had a positive impact on teachers' perceptions of their technology teaching competencies. To enrich these findings, the researchers also investigated the effect that other factors might have played a role in teachers' perceived improved technology teaching capabilities. Separate nonparametric Kruskal-Wallis analyses of variance were conducted on the overall set of differences between pre- and post-rating scores of respondents to evaluate how respondents' perceptions of their improved technology training competency were affected by the following:

- Previous or no previous exposure to technology training,
- The type of previous technology training exposure,
- The type of previous technology training,
- The type of technology qualification previously obtained,
- The institute at which the previous qualification was obtained,
- The province where the respondent was taught, and
- Previous experience teaching technology (prior to the ACE-Technology program).

The results of these analyses are summarized in Table 4, and the factors investigated are listed in column 1 of Table 4.

The analysis results identified the following biographical factors as statistically significant additional role players (over and above ACE-Technology intervention) affecting perceived general positive change in teachers' technology knowledge and understanding, namely:

i. **Previous exposure to technology training:** Teachers who had had previous exposure to technology training perceived their level of increased technology knowledge and understanding to be statistically significantly less than teachers who had no previous exposure to technology training prior to the ACE-Technology program. (The two mean differences of 0.95 and 1.36 proved to differ statistically significantly from each other).

ii. **Type of previous technology training exposure:** If previous training exposure consisted of a technology education qualification, respondents experienced significantly less change in their levels of technology knowledge and understanding when compared with technology training exposure at workshops or other modes of training exposure. (Table 4 indicates the statistically significant difference between the mean difference of 0.58 and the mean differences of 1.06 and 1.53).

iii. **Previously obtained technology qualification:** A statistically significantly greater change in knowledge perception was experienced by respondents who had attendance certificates in technology, diplomas, or a first degree in technology teaching than those with an Honors or second degree qualification (mean differences of 0.95; 0.75 and 0.75, as opposed to 0.29).

iv. Institution from which previous qualification was obtained: The respondents who obtained their qualifications from a private institution experienced significantly less change in their level of technology knowledge and understanding perception (mean difference of 0.31) than did those who had attained their qualification at a secondary school (0.97), at a college/technikon (0.83), at a university (0.81), or "on the job" (1.10).

v. Province where respondents taught: Teachers from Mpumalanga perceived a statistically significant greater increase in knowledge and understanding perception level than teachers from Gauteng.

vi. Previous experience in technology teaching: The respondents who had not previously taught technology perceived a statistically significant greater change in their level of technology knowledge and understanding than did those who had taught technology prior to the ACE-Technology program.

Discussion of Findings

The study in this paper aimed to assess the effect that the ACE-Technology training programs had on technology teachers' professional development regarding their knowledge and understanding of technology. The findings revealed that teachers overwhelmingly benefited from the training in terms of their knowledge and understanding of technology. This held true for the overall perception of improved technology knowledge and understanding competency once ACE-Technology training had been completed, as well as for the 14 specific aspects of technology knowledge and understanding

Table 4

Non-parametric Kruskal-Wallis one-way analyses of variance on pre- post-score differences to determine the significance of the role of other biographical factors on teachers' perception of improved technology teaching competencies in addition to the established effect of ACE-Technology program intervention on teaching competencies

	N Obs	Mean	Std Dev	Maximum	Minimum	*N*
Previous technology training Kruskal-Wallis Chi-sq statistic = -13.3835, probability(chi-sq statistic-value) < 0.0001***						
Yes	1750	0.9487	0.9239	3.0000	-1.0000	1656
No	2492	1.3610	1.0090	4.0000	-3.0000	2377
Type of previous technology training exposure Kruskal-Wallis Chi-sq statistic = 93.40, probability(chi-sq statistic-value) = 0.0001***						
Workshop training	1470	1.0651	0.9206	3.0000	-1.0000	1397
Tech education qualifications	308	0.5776	0.8838	3.0000	-1.0000	277
Other training exposure	84	1.5256	0.9359	3.0000	0.0000	78
Type of technology qualification obtained Kruskal-Wallis Chi-sq statistic = 22.76, probability(chi-sq statistic-value) < 0.0001***						
Attendance certificate	700	0.9451	0.9745	3.0000	-1.0000	656
Diploma	392	0.7521	0.8203	3.0000	-1.0000	359
1st Degree	84	0.7470	1.2282	3.0000	-1.0000	83
Hons/MEd/DEd	28	0.2857	0.6587	2.0000	-1.0000	28
Institute where the previous qualification was obtained Kruskal-Wallis Chi-sq statistic = 44.59, probability(chi-sq statistic-value) < 0.0001***						
Secondary school	182	0.9670	0.9337	3.0000	-1.0000	182
Technikon/College	238	0.8316	0.7627	2.0000	-1.0000	196
University	434	0.8099	1.0193	3.0000	-1.0000	426
In-job training	308	1.0976	0.9739	3.0000	-1.0000	287
Private institution	56	0.3061	0.6832	3.0000	-1.0000	49
Province where respondent taught Kruskal-Wallis Chi-sq statistic = 106.70, probability(chi-sq statistic-value) < 0.0001***						
Province						
Gauteng	2464	1.0498	0.9916	4.0000	-3.0000	2330
Mpumalanga	1750	1.3743	0.9589	3.0000	-1.0000	1691
Previous teaching experience in technology Kruskal-Wallis Chi-sq statistic = 81.78, probability(chi-sq statistic-value) < 0.0001***						
Yes	2240	1.0669	0.9397	3.0000	-1.0000	2124
No	1946	1.3479	1.0406	4.0000	-3.0000	1854

probed in the research. The initial indications of improved competency indicated in the exploratory frequency analyses were neatly statistically confirmed in the advanced statistical analysis.

Other contributing factors, expressed as biographical attributes of teachers, presented some noteworthy perspectives on the findings. Teachers who had had no previous exposure to technology education training perceived that they benefited more from the ACE-Technology program than did their peers, who had previous exposure to technology training (confirmed in deduction (i) of the *analysis results and interpretation* section). This finding may be related to these teachers' heightened determination to learn more from the training to fill their technology knowledge training gap. These findings serve to strengthen the opinion of research by the DoE (2006), Taylor and Vinjevold (1999), Jansen and Christie (1999) and Aluko (2009), who concluded that the training of many teachers (underqualified and unqualified) is still incomplete. Furthermore, results indicated that (deduction (ii), in the *analysis results and interpretation* section) teachers who had received previous technology training at colleges perceived that they benefited less from the ACE-Technology training than did those who had previous technology training exposure through workshops. The longer institutionally based technology training for the college teachers might provide the reason why these teachers perceived to have benefited less from the ACE-Technology training program: they most probably gained more knowledge and understanding of technology during their college training. An interesting finding that was not expected in the research (deduction (v), in the *analysis results and interpretation* section), is that the Mpumalanga respondents experienced a significantly greater positive change in technological knowledge post-ACE-Technology training compared with that of their Gauteng Province colleagues. This may be attributed to their higher level of commitment to acquire technology teaching capabilities because of the "the rural environment" where they work and the assumption that their rural setting is "technologically poor." Deduction (iii) in the *analysis results and interpretation* section furthermore indicated that teachers who had attendance certificates in technology perceived their acquired technology competency to have improved significantly more on ACE-Technology completion than did teachers with an Honors or second degree qualification prior to ACE-Technology training. Teachers with an Honors degree were most probably more knowledgeable at the onset of ACE-Technology training. Deduction (vi) of the *analysis results and deductions* section also indicated that teachers who had not previously taught technology perceived to have benefited significantly more from the ACE-Technology training than did those who had taught technology previously. The latter group most probably had ample exposure to technology prior to ACE-Technology training, and they could therefore identify with what the ACE-Technology training covered. These findings confirm that the benefit that these categories of teachers derived from the training based on their biographical attributes is in keeping with DoE's (2006) intention with ACE programs – for teachers to become specialists in their subject areas.

Recommendations

Technology teacher training should be preceded by profiling teachers and analyzing needs so that strategic decisions can be made to vary the depth and nature of the training based on the profile and specific needs; otherwise, the training may not be beneficial to all. Teachers without any training background in technology should preferably receive intensive training in all content knowledge and pedagogical areas. For those with some training background, only specific gaps as identified in their needs survey should be addressed in the training. Furthermore, because a quantitative research approach (as was followed in the current research) might have presented as a limiting factor in knowledge acquisition on the dynamics of perceived benefits to be gained from ACE-Technology training, researchers should consider mixed-methods approaches for the assessment of the impact of training on technology teachers in future studies. Such an approach will enable triangulazation. The current exploratory study was also restricted to only two provinces in South Africa. In the future, a study of this nature should be extended to other provinces to be able to generalize to South Africa as a whole.

Conclusion.

This paper reported the findings of the study that inquired into the effect of ACE-Technology training of teachers regarding their knowledge and understanding of technology. In terms of the research question and the hypothesis that was stated, the main finding of the study is that the ACE training in technology education enhanced teachers' knowledge and understanding of technology. This is an important finding considering that technology education is a relatively new learning area/subject and that there is dire need for training teachers to offer the same to learners. Furthermore, the training of teachers in the field should be seen to make a difference in their knowledge of technology and the methodologies of presenting it to the learners. It is hoped that teachers who underwent this training are now serving their learners in schools by implementing what they have acquired.

Dr Mishack Gumbo is a senior lecturer in the Science and Technology Education Department, College of Education at the University of South Africa.

Dr. Moses Makgato is an associate professor in the Department of Educational Studies at Tshwane University of Technology, South Africa.

Heléne Müller is a senior research support consultant in the Department of Interdisciplinary Research, College of Graduate Studies at the University of South Africa.

References

Aluko, R. F. (2009). The impact of an Advanced Certificate in Education (ACE) Program on the professional practice of graduates. *International Review of Research in Open and Distance learning*, 10(4), 1-15.

Borko, H., Elliot, R. L., McIver, M. C., & Wolf, S. A. (2000). "That dog won't hunt": Exemplary\ school change efforts within the Kentucky reform. *American Educational Research Journal,* 37(2), 349-393.

Brown, C., Sithole, V., & Hofmeyr, R. (2000). South Africa: Teacher training in the sky. *TechKnowlogia*, 53-54.

Castellano, M., & Datnow, A. (2000). Teachers' responses to success for all: How beliefs, experiences, and adaptations shape implementation. *American Educational Research Journal*, 37 (3), 775-799.

Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Education Policy Analysis Archives*, 8 (1), 1-49.

Department of Education. [DoE]. (2000). Norms and Standards for Educators. Pretoria: Government Printers.

Department of Education. [DoE]. (2003). Revised National Curriculum. Pretoria: Government Printers.

Department of Education. [DoE]. (2005). Revised National Curriculum. Pretoria: Government Printers.

Department of Education. [DoE]. (2006). The national policy framework for teacher education and development in South Africa: More teachers; better teachers. Pretoria: Government Printers.

Department of Education. [DoE]. (2009). Teacher Qualification Survey: Draft report prepared by Human Sciences Research Council for Department of Education.

Department of Education. [DoE]. (2010). Curriculum and Assessment Policy Statement (draft document). Pretoria: Government Printers.

Feng ,W., & Siu, K. W. M. (2009). Professional development for technology teachers in Mainland China and Hong Kong: Bridging theory and practice. A paper presented at the PATT22 conference held between 24-28 in Delfti.

Gumbo, M. T. (2003). Indigenous technologies: Implications for a technology education curriculum. (Unpublished PhD thesis). Pretoria: Vista University.

Jansen, J., & Christie, P. (Eds). (1999). Changing curriculum studies on OBE in South Africa. Pretoria: Juta & Co Ltd.

Kent, A. M. (2004). Improving teacher quality through professional development. Retrieved from http://findarticles.com/p/articles/mi_qa3673/is_3_124/ai_n29092860.

Laine, S. W. M., & Otto, C. (2000). Professional development in education and the private sector: Following the leaders. Oak Brook, IL: North Central Regional Educational Laboratory.

Maluleka. K., Wilkinson. A., & Gumbo. M. (2006). The relevance of indigenous technology in Curriculum 2005/RNCS with special reference to the Technology Learning Area. S*outh African Journal of Education*, 26(4), 501-513.

Ndahi, H. B., & Rit, J. M. (2003). Technology education teacher demand, 2002-2005. *The Technology Teacher*, 27-31.

Ono, Y., & Ferreira, J. (2010). A case study of continuing teacher professional development through lesson study in *South Africa. South African Journal of Education*, 30, 59-74.

Pikulski, J. J. (2000). Increasing reading achievement through effective reading instruction (Tech.Rep.No. 19716). Newark, DE: University of Delaware, School of Education.

Potgieter, C. (2004). The impact of technology education, as a new learning area, on in-service teacher education in South Africa. *International Journal of Technology and Design Education*, 14, 205-218.

Rivers, J. C., & Sanders, W. L. (1996). Cumulative and residual effects of teachers on future student academic achievement. Knoxville: University of Tennessee Value-Added Research and Assessment Center.

Taylor, N., & Vinjevold, P. (1999). Getting learning right: Report of the president's education initiative project. Johannesburg: The Joint Education Trust.

Villegas-Reimer, E. (2003). Teacher professional development: An international review of the literature. Paris: International Institute for Educational Planning.

Welch, T. (2009). Teacher education qualifications: Contribution from Tessa Welch to working paper for teacher development summit – 27 May 2009.

Voices from the Past: Messages for a STEM Future

Todd R. Kelley

ABSTRACT

The current emphasis in K-12 education on science, technology, engineering, and mathematics (STEM) (Douglas, Iversen, & Kalyandurg, 2004; Sanders, 2009) creates many ways to partner engineering education with these fields. Therefore, it is appropriate to examine the commonalities these fields have with engineering education. Though much of the science education and mathematics education history is understood, technology education's history is not common knowledge, and as a result misconceptions abound (Daugherty & Wicklein, 1993 Wicklein, 2008). Technology education's longstanding history in problem- and project-based learning, design- and engineering-related pedagogical approach is over a century old and grounded in theories of Comenius, Rousseau, Pestalozzi, Froebel, Herbart, Sheldon, and Dewey (Dewey, 1915; Foster, 1995, 1997; Herschbach, 2009; Kirkwood, 1994). The brief review of technology education's history will reveal an almost eerie parallel to the current engineering education and STEM education movements.

Key Words: technology education, K-12 STEM education, project-based Instruction, design-based instruction

Introduction

Although other authors have visited various historical milestones in technology education origins such as manual arts, manual training, industrial arts, industrial technology (Bonser, 1926; Foster, 1995, 1997; Herschbach, 2009; Scott & Sarkees-Wircenski, 2004), this article will highlight some less explored milestones within technical education that provide opportunity for reflection on the current position held by technology education regarding the STEM paradigm. Some milestones featured here cross paths with early American engineering programs that emphasized project-based instruction while other milestones promote design-based instruction within technology education and general K-12 education. Finally, the focus of this historical journey will conclude with recent milestones that integrate core subjects with technology education. Recent approaches to K-12 STEM education appear to mix of these various pedagogical approaches to integrate the four subjects (science, technology, engineering, and mathematics); thus, this provides the rationale to revisit these voices of the past to speculate what these milestones might indicate for the success of a the T in STEM. Figure 1 illustrates both the milestones that are featured in this article and a general progression that led to the current STEM movement. Although many technology education milestones are not featured in this article, those selected here provide insight not only for technology education but also for engineering education, the two often-neglected members of the greater STEM community.

Early Design-Based Instruction

American's early educational movement in the field better known today as technology education was heavily influenced by European education pioneers (Herschbach, 2009). The father of the modern kindergarten movement, Friedrich Froebel, first studied under Johann Heinrich Pestalozzi. Both educational reformers believed heavily in educating children in a full range of real-life activities and using a hands-on approach to teaching. Pestalozzi focused on the object lesson, that is, using objects for concrete observations, which was later brought to the

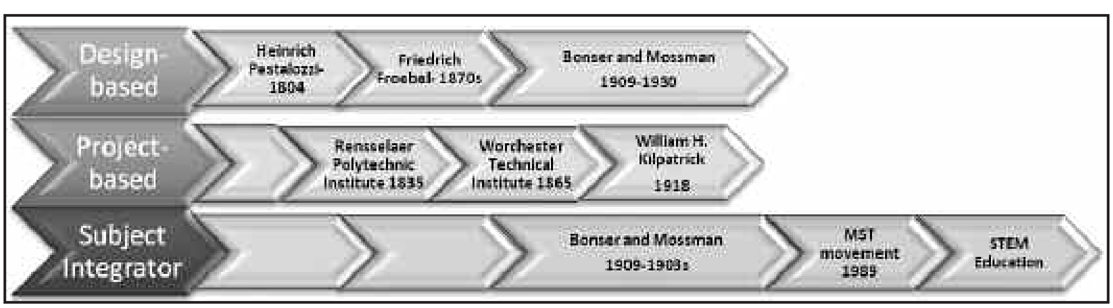

Figure 1. Technology and Engineering Education Milestones Leading to a STEM future.

United States by Edward Austin Sheldon (Foster, 1995). Pestalozzi began this work with orphans in Switzerland in 1804. Another pedagogical hands-on approach used by Pestalozzi was combining sketch work as a way to teach children how to learn and write letters from the alphabet. Froebel studied Pestalozzi's methodologies and developed his own theoretical framework on the three realms, which included forms of nature (or life), forms of knowledge (or science), and forms of beauty (or art). These realms were introduced to children via short sessions of guided play with building blocks, mosaic toys, and traditional crafts. Children were taught to look for the mathematical equations in these objects.

> The ultimate lesson of kindergarten was straightforward: the forms of the world, mathematics and art are equivalent and interchangeable. A chair made of eight cubes might become the number eight, then a pinwheel design, then a bed and so on. (Brosterman, 1997, p. 111)

Frobel actually marketed children's building kits (e.g., manufactured by E. Steiger & Company and A. N. Myers & Company) in the 1860s-1870s as a way to study design and geometry. These kits included stick and cork geometric form building kits, carefully proportioned maple wood building blocks, colored cardboard triangles, and even child-size grid tables as a work surface to guide geometric pattern construction (Brosterman, 1997).

Famous American architect, Frank Lloyd Wright was given these Frobel toys as a child. He credited his success in architecture with his early childhood experiences using the grid table, cardboard shapes, and the maple wood blocks. He believed the Frobel gifts were foundational to developing his abilities to design later in life (Brosterman, 1997; Coleman, 2008). As engineering education and other STEM efforts seek to teach young learners about design and engineering, these STEM stakeholders should consider revising Frobel's methodologies as tools to teach design. Consider recent engineering education efforts to teach children about engineering using toys such as LEGO® building blocks (Capozzoli & Rogers, 1996; Connolly, Wendell, Wright, Jarvin, & Rogers, 2010; Erwin, Cyr, & Rogers, 2000). Frobel is just one of many unlikely educational pioneers who influenced the field of technology education; he is considered an unlikely influencer because his contribution is neither technical nor vocational, but it is design and aesthetically focused.

Technology Education for All

Other pioneers in the history of technology education also focused on the design and aesthetics of the study of technology. Frederic Bonser and Lois Coffey Mossman had a profound influence on the early beginnings of technology education, and much of their work focused on the elementary grades. Bonser and Mossman believe that all children should receive manual training and industrial education, and the purpose was social reform, not vocational education. Mossman is credited for being the first person to use the term Industrial Arts by 1909, when she proposed the combination of manual training, drawing, and home economics in elementary and middle grades (Foster, 1995). In addition to aligning the school's practical work with the traditional curriculum, Mossman emphasized the need for students to design their own projects. When learning about clothing, some students designed and made their own shirtwaists; when learning about shelter, students planned and drew houses ("On the ground floor," Coffey-Mossman, 1907, p. 123, in Foster, 1995). Although Bonser and Mossman provided many publications outlining their educational philosophies related to industrial arts (Bonser, 1911, 1926,1932; Bonser & Mossman, 1923; Mossman, 1924, 1929, 1938) much of their conception of industrial arts was lost when implemented in the classroom (Foster, 1995). This example should serve as a warning to STEM education leaders and educational policy makers that theory (educational philosophy) and practice (in-service teacher pedagogy) do not always mesh. If researchers of STEM fail to thoroughly investigate the complexities surrounding teacher practices that integrate STEM, the recent efforts to infuse STEM education into the classroom will be void.

Project-based Learning in Technology Education and Engineering

The early roots of technology education are closely intertwined with the development of the American engineering schools. Van Rensselaer, founder of Rensselaer Polytechnic Institute (RPI) in Troy, New York, along with Amos Eaton are credited for creating a university founded on teaching of the sciences through practical application, such as applying mechanical philosophy to the machinery of steamboats, mills, and factories. The practical applications of science at Rensselaer also included surveying land; calculating water pressures in locks, aqueducts, and dams; and designing and planting experimental gardens. These examples of pedagogical approaches to the sciences led to the founding of a department of Mathematical Arts at Rensselaer in 1835 "for the purpose of giving instruction in Engineering and Technology" (Bennett, 1926, p. 353). This is the first example of an American civil engineering school in the United States; four students graduated from RPI with civil engineering degrees in 1835, and before that time civil engineers were imported from France to build U.S. canals and bridges (Bennett, 1926).

Another important early American school of mechanical engineering that combined the theory and practice of engineering through scientific reasoning and shop experience was the Worcester Technical Institute in Worcester, Massachusetts, which was founded in 1865. Several donors, including John Boynton and Ichbod Washburn, two prominent Worcester industrialists, helped to make the Worchester Technical Institute a reality. It was Washburn, however, who added a unique element to the school curriculum; he wanted to teach vocational skills while Boynton wanted to teach science. A machine shop was donated to the institute to provide practical application to the science instruction. "Thus it came about that a new type of mechanical engineering course was made possible—a course which combined experience in a shop . . . and a theoretical course in applied science and engineering" (Bennett, 1926, p. 360). Bennett (1926) wrote that the shop was not for manual or industrial training but for educational purposes; the machine shop was considered as educational as a laboratory is to science. The work done in the machine shop was to be a substitute for an apprenticeship while the students simultaneously took mathematics, science, and engineering courses (Bennett, 1926). The news spread about the success of this educational approach and other universities around the country began to introduce shop work into their engineering programs (Scott & Sarkees-Wircenski, 2004). Although there were proponents of the practical application of mathematics, science, and engineering through hands-on manual education, many people during the decade from 1880-1890 had great opposition to manual training in K-12 classrooms, and as a result, the gap between academic subjects and hands-on activities began to widen (Bennett, 1926).

If one fast-forwards from Rensselaer's 1835 era of practical application of engineering education to engineering education in the 21st century, one can make an eerie parallel. Authors Dym, Agogino, Eris, Frey, and Leifer (2005) explored the complexity of engineering design thinking and how design is best taught in engineering. Interestingly, these authors cited project-based learning (PBL) as the most favorable pedagogical approach for teaching design within engineering education. Moreover, Dym et al. (2005) suggested that the best context for PBL is first-year engineering cornerstone courses because it delivers a key element understood in cognitive science *transfer of learning* which "allows students to apply what was learned in new situations and to learn related information more quickly" (Bransford, Brown, & Cocking, 1999, p. 17). Dym et al. (2005) also indicated that PBL motivates students to learn upper level engineering sciences and helps with student retention in engineering schools. Brophy, Klein, Portsmore, and Rogers (2008) provided a comprehensive overview of engineering education curriculums and research efforts in P-12 classrooms within the United States, and once again PBL and other hands-on design-based instruction dominate the highlighted pedagogical approaches. The original founder of the project-based learning (PBL) concept was William Heard Kilpatrick. In September of 1918, Kilpatrick presented this theory of learning in an essay titled *The Project Method*, which emphasized "purposeful activity" to engage students in the learning process as they worked on a variety of projects. At the time, this new pedagogical approach was so popular that over 60,000 copies of the essay were published in pamphlet form (http://www.answers.com/topic/william-h-kilpatrick); later this information was published in book form entitled *Foundations of Method* (Kilpatrick, 1925). It was widely accepted in technology education (Industrial Arts) during that era.

> It was also an attractive idea that activity could serve as the center for correlating subject matter from a number of subject areas, such as English, math, science, and industrial arts. In this way, students could learn how to apply formal knowledge to the immediate concerns of their daily lives. (Herschbach, 2009, p. 33-34)

The current proposed approaches to K-12 STEM education and design- and project-based engineering education have origins in the works of both Kilpatrick and Rensselaer and the ideas of the Worcester Technical Institute. Some of the concepts of Rensselaer's engineering school of 1835 live on in today's modern engineering programs. Purdue's Neil Armstrong Hall of Engineering was completed in 2008. This new faculty includes multiple material testing and fabricating laboratories to provide hands-on design experiences. According to the Purdue University website, "Industry is demanding engineers who have traditional technical expertise along with design and building experience, often on industrial scale projects, and who can work in diverse teams" (see https://engineering.purdue.edu/Engr/AboutUs/Facilities/ArmstrongHall/Features/). These are several of examples of the history of technology education and engineering that illustrate that both fields are returning to their pedagogical roots by providing practical applications of design and engineering instruction. Although both fields often promote these methods as new innovations, the reality is that these approaches to education are well over a century old.

Technology Education is a Subject Integrator

There are many examples of subject integration within the history of technology education that can provide lessons to the STEM community. It is likely that current technology educators would be shocked to find so many examples of subject integration within the early forms of technology education (manual arts, manual training, and industrial arts). "Current efforts in technology education to integrate math, science, and technology also have an extensive heritage, although much of that heritage has either been neglected or ignored" (Pannabecker, 2004, p. 78). The industrial arts pioneer, Lois Coffey Mossman repeatedly emphasized in her writings that the integration of school subjects could be achieved through practical classroom activities. For example, she discussed the use of poems in a lesson in agriculture. Mossman emphasized the need to connect the study with arithmetic, geometry, reading, art, geography, nature study, physics, and botany (Coffey as cited in Foster, 1995). Although the roots of technology education as a subject integrator grow deep, what has occurred in the classroom provides little solid evidence of a widespread effort to use technology education as a vehicle to integrate subjects. Sanders (2009) indicated that technology education teachers like to boast about teaching science and mathematics but often fail to do so in practice. However, in the late 1990s, there were some efforts to reform the curriculum to conscientiously integrate math, science, and technology.

The MST Approach

One example of an educational approach to include technology education through a multidisciplinary approach to improve mathematics and science was the MST movement. Many educational leaders in the early 1990s recognized the need to improve American students' scores in science and mathematics. Documentation of the status of student achievement in math and science during this time can be found in reports such as *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (National Research Council, 1989) and *Project 2061: Science for All Americans* (American Association for Advancement of Science, 1989). One approach considered to improve scores in these core subjects was to include technology education though design-based instruction as a way to provide a context for learning math and science. Many technology educators believed the MST approach as an outstanding opportunity for the field to be included with core subjects to provide exposure of technology education to all learners. Laporte and Sanders (1993) believed that the MST approach would improve the status of technology education; however, there were other leaders who wondered if technology education would become a stepchild in the 'marriage of math and science' (Foster, 1994; Gloeckner, 1991). Daugherty and Wicklein (1993) probed deeper to determine math, science, and technology teachers' perceptions of technology education. Their findings revealed that some misconceptions and poor perceptions of technology educators and the field technology education existed. Possible reasons for misconceptions about technology education were stated previously based upon the general public's exposure to industrial arts. Hansen (1995) in a study on teacher socialization within technology education provided another possible explanation. Hansen's study found that technology education teachers tend to congregate with peers within the field of technology education and as a result fail to connect with the greater learning community. Therefore, the technology educators have limited impact on how teachers in other content areas view and perceive the technology education field and local technology programs. This discovery within technology education should be considered as teacher professional development brings together STEM teachers to collaborate to integrate STEM disciplines within the classroom.

One of the best examples of the MST approach was the New York State Technology Education Network (NYSTEN), a project funded by the National Science Foundation. The goals of NYSTEN were to provide contemporary approaches of technology education, conduct educational research on technology education classrooms, and provide professional development opportunities and leadership opportunities to technology educators across New York State (Burghardt & Hacker, 2002). The MST movement began to die out when federal dollars ran out, such as Goals 2000 funding, and the MST approach lost significant momentum. Efforts such as the MST standards document for New York state were not implemented as originally designed. High stakes testing also played a role in ending the MST movement in New York. The New York State Education Department website states the following:

> Through the foresight of many, the standard for technology and technology education programs was linked to mathematics and science. Illustrating the interconnectedness of these three subjects the Mathematics, Science, Technology (MST) Learning Standards has created a dynamic force for demonstrating student knowledge. While mathematics and science have had a long history in education, technology education is a relatively new subject with less stature and acceptance. Added to this the testing pressures placed on mathematics and science education, technology education has been overlooked as a tool for improving student achievement. (New York State Education Department, 2006, p. 4)

These examples reiterate the concerns of Gloeckner (1991) and Foster (1994), and others leaders who believe that technology education will never be considered a viable school subject required for study by all students. The greater STEM community must learn from these past events in order to ensure that all STEM stakeholders are well understood. Unfortunately, the leaders from the MST movement failed to fully investigate the complexities of the community of MST teachers; therefore, there was little effort to overcome negative stereotypes or misconceptions of the three subject domains that often stifled building strong teacher partnerships.

Communicating a Clear Mission

Technology education is a very broad term, and that large scope may contribute to its the many misperceptions. Furthermore, there are multiple purposes for teaching technology education in secondary education that have caused great confusion about the purpose of technology education. Although many technology educators today would contend that technology education is important for all students (ITEA, 1996) and that this has been the general mission of technology education since the early 1900s (Foster, 1997); however, there are other educators who focus on technology education as a career pathway. Foster and Wright (1996) document the tension in the 1970s between proponents of industrial arts education for all students versus vocational education. Both purposes of technical education existed and completion for students and funds split resources as well as continued to blur the mission of technology education. Today, divisions still exist in professional teacher education associations with the simultaneous existence of the Technology Education Division (TED) within the Association for Career and Technical Education (ACTE) and International Technology and Engineering Education Association (ITEEA) (Hill, 2006). There are many authors who have written about the lack of uniformity within technology education (Petrina, 1993; Wicklein, 2006; Wright, 1992).

As the engineering education community continues to approach the K-12 arena, it will be critical that engineering educators examine this page from technology education's history. Engineering education must define the main purpose of its role in K-12 education. Is the purpose to improve STEM learning for all children or is the purpose to provide a career pipeline to engineering? Currently, the engineering education literature suggests that both missions for K-12 engineering education exist (Brophy et al., 2009; Douglas et al., 2004; National Academy of Engineering, 2004; Committee on Prospering in the Global Economy of the 21st Century, 2007). Moreover, the funding opportunities that exist in STEM education can cloud the mission of any educational venture. Currently there are over 45 NSF programs that include STEM somewhere in the RFP solicitation (www.nsf.gov, date accessed 5/30/12). Back in 2009, a $100 million of the $787 billion stimulus package was designated for the National Science Foundation (Riley, 2009). In technology education, this "clouding the mission" occurred as early as the late 1800s. Lewis (1996) cited Woodward (1894) as a proponent of manual arts for all children's general education who compromised his ideals of a liberal education of manual arts to an approach to manual training as trade training to acquire needed funds from the Smith-Hughes Act of 1917. Current concerns within the technology education community exist about aligning with engineering education and the greater STEM movement—this could cloud the mission of technology education. "If engineering groups start exercising too much influence on technology education, our field risks a greater association with engineering's vocational or professional orientation, its perceived loyalty to business, and its traditional political alliances" (Pannabecker, 2004, pp. 79-80). Another concern for technology educators is t hat "by focusing heavily on pre-engineering, technology education also is 'vocationalized' to the extent that it is limited primarily to prepare youth to enter into a specific occupational field" (Herschbach, 2009, p. 240). It is quite possible that members of technology education express these concerns because engineering education has not communicated its intentions or purpose for K-12 engineering education.

Salinger (2005) has suggested that the study of K-12 engineering should not be vocational but it should be taught as a way of thinking. In his paper *The Engineering of Technology Education*, he challenges technology educators to use the process outlined in *Understanding by Design* (Wiggins & McTighe, 2005) to help the field of technology education establish its mission regarding teaching engineering within technology education. Salinger (2005) suggested technology educators ask themselves the question, "What is the goal?" In other words, they should identify what the purpose is to infuse engineering concept into technology education. The author of this article believes the same question can be applied to engineering education regarding its role in K-12 education: What is the goal?

Conclusion

The overarching purpose of this article was to share some commonalities between technology education and engineering education and strong, almost eerie parallels of technology education history with engineering education and the current STEM education movement. Salinger (2005) provided this challenge to the field of technology education:

> The technology education profession has worked hard on the issue of the content of its discipline and on how to be educated to teach it (ITEA, 2000/2002); but perhaps needs to think more strategically about other dimensions like where can it get support? (p. 3)

The author of this article would like to suggest that T and the E should work harder to provide support for one another. Of all the STEM stakeholders who sit at the "STEM table," members of the technology and engineering fields are best positioned to sit the closest; as a result their contribution to K-12 STEM education will be strengthened. Consider the words of engineering educators Haghighi, Smith, Olds, Fortenberry, and Bond (2008) as they spoke regarding engineering education's future: "We must form win-win partnerships not only in areas such as cognitive science but also in the interdisciplinary context of the larger engineering college as well as the K-12 community and community colleges" (p. 120).

Taking a page from Frans Johansson's (2004) best-selling book: *Medici Effect: Groundbreaking Innovation at the Intersection of Ideas, Concepts, & Cultures*, the author of this article suggests that technology education and engineering education strengthen their positions within STEM by locating the key intersections within these fields of study. If fields suffer from a lack of a clear mission, partnering to explore common intersections would be prudent. Possibly one of the greatest opportunities to begin to define a clear mission is to simultaneously establish a clear research agenda. What are the intersections between a technology education research agenda and an engineering education research agenda? This author believes that both fields must discover through research the benefits that exist in teaching engineering in K-12 classrooms. Does teaching in the context of engineering design improve students' STEM learning? These are just a few questions that should be asked by researchers within technology education and engineering education. Unfortunately with current state's budget constraints in K-12 education, the T and the E are in possible jeopardy of funding cuts; some cuts have already occurred. It is now time to conduct rigorous research that speaks loudly to policy makers—a strong partnership between the T and the E can begin to build a clear research agenda.

Dr. Todd R. Kelley is an assistant professor in the College of Technology (and P-12 STEM Researcher) at Purdue University, West Lafayette, Indiana. He is a member of Phi Chapter of Epsilon Pi Tau.

References

American Association for Advancement of Science. (1989). *Project 2061: Science for all Americans.* Washington, DC: Author.

Bennett, C. A. (1926). *History of manual and industrial education up to 1870.* Peoria: Bennett.

Bonser, F. G. (1911). Fundamental values in industrial education. *Teachers College Bulletin III* (November 18). New York: Teacher's College, Columbia University.

Bonser, F. G. (1926). *A history of industrial arts in Teachers College, to May, 1926.* [Unpublished manuscript, Milbank Memorial Library, Teachers, College, Columbia University, New York.]

Bonser, F. G. (1932). Bibliography. In *life needs and education* (pp. 271-288). New York: Teachers College, Columbia University.

Bonser, F. G., & Mossman, L. C. (1923). *Industrial arts for elementary schools*. New York: Macmillan.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). (Eds.). *How people learn: Brain, mind, experience, and school,* Washington, DC: National Academy Press.

Brophy, S., Kelin, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education.* 369-382.

Brosterman, N. (1997). Child's play. *Art in America, 85*(4), 108-111, 130.

Burghardt, D., & Hacker, M. (2002). Large scale enhancement projects focusing on technology education. *Journal of Industrial Technology Education, 39*(3), 88-103.

Capozzoli, P., & C. Rogers. 1996. LEGOs and aeronautics in kindergarten through college In *Proceedings of the Advanced Measurement and Ground Testing Technology Conference*. New Orleans, LA.

Coleman, D. (2008). Long before Legos, wood was nice and did suffice. The New York Times, 11.

Connolly, K. G., Wendell, K. B., Wright, C. G., Jarvin, L., & Rogers, C. (2010). Comparing children's simple machines learning in LEGO(TM) engineering-design-based and non-LEGO engineering-design-based science environments. Paper presented at the Annual International Conference of the National Association for Research in Science Teaching (NARST), Philadelphia, PA.

Committee on Prospering in the Global Economy of the 21st Century (2007). Rising above the gathering storm: Energizing and employing America for a brighter economic future. National Academy of Science. Washington, DC: National Academies Press.

Daugherty, M.K., & Wicklein, R.C. (1993). Mathematics, science, and technology teachers' perceptions of technology education. *Journal of Technology Education, 4* (2), 28-43.

Dewey, J. (1915, May 15). Education vs. trade-training. *New Republic*, pp. 40-43.

Douglas, J., Iversen, E., & Kalyandurg, C. (2004). Engineering in the K-12 classroom: An analysis of current practices and guidelines for the future. A production of the ASEE Engineering K12 Center.

Dym, C., Agogino, A., Eris,O., Frey, D., & Leifer, L (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education, 95*(1), 103-120.

Erwin, B., Cyr, M., & Rogers, C. 2000. LEGO engineer and ROBOLAB: Teaching engineering with LabVIEW from kindergarten to graduate school. I*nternational Journal of Engineering Education* 16(3), 181–92.

Foster, P. (1994). Must we MST? *Journal of Technology Education, 6*(1), 76-84.

Foster, P. N. (1995). The founders of Industrial Arts in the U.S. *Journal of Technology Education. 7*(5), 6-21.

Foster, P. N. (1997). Lessons from history: industrial arts/ technology education as a case. *Journal of Vocational and Technical Education*, 13(2), 5-15.

Foster, P. N., & Wright, M. D. (1996). Selected leaders' perceptions of approaches to technology education. *Journal of Technology Education, 7*(2), 13-27.

Gloeckner, G. (1991). The integration of science, technology, and mathematics myth or dream? *Journal of Technology Education, 2*(2) 1-7.

Haghighi, K., Smith, K.A., Olds, B. M., Fortenberry, N., & Bond, S. (2008). The time is now: Are we ready for our role? *Journal of Engineering Education, 97*(2), 119-121.

Hansen, R. E. (1995). Teacher socialization in technological education. *Journal of Technology Education, 6*(2), 34-45.

Herschbach, D. (2009). *Technology education: Foundations and perspectives.* Homewood, IL: American Technical Publishers, Inc.

Hill, R. B. (2006). New perspectives: Technology teacher education and engineering design. *Journal of Industrial Teacher Education, 43*(3), 45-63.

International Technology Education Association. [ITEA]. (1996). *Technology for all Americans: A rationale and structure for the study of technology.* Reston, VA: Author.

International Technology Education Association. [ITEA]. (2000/2002) *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author.

Katehi, L., Pearson, G., & Feder, M. (Eds.). (2009). *Engineering in K-12 education: Understanding the status and improving the prospectus.* Washington, DC: National Academies Press.

Johansson, F. (2004). *The Medici effect: Breakthrough insights at the intersection of ideas, concepts, & cultures.* Cambridge, MA: Harvard Business School Press.

Kirkwood, J. J. (1994). Construction in elementary school technology education. In J. W. Wescott & R. H. Henak (Eds.). *Construction in technology education* (pp. 75-101). Peoria, IL: Glencoe.

Kilpatrick, W. H. (1918, September). The project method. *Teachers College Record, 19*(4), p. 319–35.

Kilpatrick, W. H. (1925). *Foundations of method*. New York: Macmillan.

LaPorte, J., & Sanders, M. (1993). Integrating technology, science, and mathematics in the middle school. *The Technology Teacher, 52*(6), 17-21.

Lewis, T. (1996). Accommodating border crossings. *Journal of Industrial Teacher Education, 33*(2), 7-28.

Mossman, L. C. (1924). *Changing conceptions relative to the planning of lessons.* New York: Teachers College, Columbia University.

Mossman, L. C. (1929). The content of the social studies in the elementary school. *Teachers College Record, 30*(4), 322-333.

Mossman, L. C. (1938). *The activity concept: An interpretation.* New York: Macmillan.

National Academy of Engineering. (2004). *The Engineer of 2020*. Washington, DC: The National Academy Press.

National Research Council (1989). *Everybody counts: A report to the nation on the future of mathematics education.* Washington, DC: National Academy Press.

New York State Education Department. (2006). NYS Technology Education Framework Initiative, p. 4. Retrieved September, 15, 2009. http://www.emsc.nysed.gov/cte/technology/initiative/home.html

Pannabecker, J. (2004). Technology education and history: Who's driving? *Journal of Technology Education, 16*(1), 72-83.

Petrina, S. (1993). Diversity, not uniformity united, not standardized: A reaction to Wright's "challenge to all technology educators." *Journal of Technology Education, 4*(2), 69-76.

Riley, S. (2009, March, 10). Tech education will get some funding from stimulus effort. *Investor's Business Daily Inc.*

Salinger, G. (2005). The engineering of technology education. *Journal of Technology Studies, 31*(1), 2-6.

Sanders, M. (2009) STEM, STEM education, STEMmania. *The Technology Teacher, 68*(4). 20-26.

Scott, J. L., & Sarkees-Wircenski, M. (2004). *Overview of career and technical education.* Homewood, IL: American Technical.

Wicklein, R. C. (2006). Five good reason for engineering design as the focus for technology education. *The Technology Teacher, 65*(7), 25-29.

Wiggins, G. P., & McTighe, J. (2005). *Understanding by design.* (2nd ed.). Alexandria, VA: Association for Supervision and Curriculum Development.

Woodward, C. (1894). *New demands upon schools by the world's industries.* Proceedings of the International Congress of Education of the World's Columbian Exposition, New York: National Education Association.

Wright, T. (1992). Building a defensible curriculum base. *Journal of Technology Education, 3*(2), 62-66.

Nanotechnology Safety Training: Addressing the Missing Piece

Dominick E. Fazarro and Walt Trybula

Abstract

This OSHA Susan Harwood Grant addressed nanotechnology safety training for workers and was critical for building a path for future training/education courses. The purposes of the grant were to facilitate training and to assess the outcomes of the participants' knowledge. Two trainers went to four sites in the United States, including one in Puerto Rico, to conduct eight-hour courses in the Environmental, Health, and Safety (EHS) implications of nanomaterials

A survey was distributed to participants at the end of the course to assess the quality of the course and the instructors. Overwhelmingly, approximately 95% of the participants were satisfied with the quality of the course and instruction.

A pretest was given to the participants to assess if they knew anything about EHS, and a posttest was administered after the training course. A hypothesis test was used to determine the effectiveness of the content of the course. A paired samples t-test was used to ascertain whether there was an improvement in scores from the pretest to the posttest. The findings indicated a statistically significant difference between the group mean scores from the pretest to the posttest. In essence, the participants improved from the pretest to the posttest scores as a result of the training. However, there are caution should be taken when addressing the results as the sole indicator of the participants' success.

Introduction

The purpose of this article is to illustrate the findings/assessment of the program funded by an OSHA Susan Harwood Grant. Although huge amounts of data were collected for this article, the authors displayed only data that directly addressed the research questions.

Nanotechnology is emerging as the next frontier of cutting-edge science and engineering. Nanotechnology has provided researchers and industry with a new avenue to develop products that may revolutionize the world as we view it. The National Nanotechnology Initiative has estimated that by 2015, the economic global impact of nanotechnology could reach around $1 trillion (Wedin, 2006). Industry has the monumental challenge of preparing a workforce to think and develop below the 100-nanometer (nm) level. Working with materials on the nanoscale requires specialized training and a technical background that is needed to manufacture engineered nanomaterials (ENMs) (Trybula, Fazarro, & Kornegay, 2009). Researchers, technicians, manufacturing engineers, and production workers will be needed for a nanotechnology workforce (NNI, 2009). Dr. Mihail Roco, NSF Senior Advisor on Nanotechnology, is one of the leaders promoting nanotechnology workforce education/training. By 2015, there will be approximately two million workers globally in nanotechnology (Roco, 2003). Roco stressed the training of people is vital for long-term success in the field of nanotechnology (Roco, 2001).

Workers are producing carbon nanotubes in various applications (e.g., conductive plastics and aeronautical uses) (Nanocyl, 2009). The workforce in these types of companies, such as SouthWest NanoTechnologies, Bayer, and Nanocomp Technologies, which produce ENMs is estimated to contain at least 620 workers. The estimated growth for this product is at an annual pace of 15-17%, and this represents only one of many different classes of nanomaterials (Nanoparticle Task Force ACOEM, 2011). A report identified 61 U.S.-based companies that manufacture or handle carbon-based nanomaterials, in particular carbon nanotubes (Nanoparticle Task Force ACOEM, 2011). This report is disturbing because 61 companies may have inadequate safety procedures for workers who handle EMNs, and most important, workers may not have the proper training to identify potential hazards, which may be very dangerous to welfare of workers and others outside the confines of the workplace. According to studies, some carbon nanotubes—the most researched and produced in the industry, from a technological and toxicological viewpoint—have produced asbestos-like symptoms in rodents (Takagi, Hirose, & Nishimura, 2008). Moreover, work is needed to research both the physical and chemical properties of nanomaterials and how these properties relate to unwanted health effects. The properties of nanomaterials cannot be generalized to determine health and safety effects (Fazarro & Trybula, 2011). As new EMNs emerge, there is an increase in the uncertainty of how they will behave (Shatkin et al., 2010). Research about the properties of EMNs will be ongoing; however, there is a need to properly train U.S. nanoworkers in safety.

National and Global Perspective on Nanotechnology Safety

A number of government organizations, such as CDC, NIOSH, NIST, FDA, and ICON, are aggressively establishing a foundation to define fundamentals of nanotechnology safety content. In 2011, the following government organizations were funded to address the research needs to maintain a safe workplace: The U.S. Food and Drug Administration (FDA) requested $15 million; The National Institute for Occupational Safety and Health (NIOSH) requested $16.5 million; and the National Institute for Standards and Technology (NIST) doubled its nanotechnology safety research from $3.6 to $7.3 million (Maynard, 2010). According to Fazarro & Trybula (2011), “This effort to push nanotechnology safety research is novel; however, there is a need for a parallel effort to implement education and training” (para 4). Maintaining workers’ health and avoiding litigation would be a beneficial by-product of avoiding accidents that can result to public mistrust. So, what should be done to prepare this growing workforce to meet the needs of the industry?

U.S. Senators Mark Pryor and Benjamin L. Cardin have introduced the Nanotechnology Safety Act of 2010 (Pryor, 2010) to address future health and safety concerns. According to Mark Pryor:

> Nanotechnology is one of the most important and enabling technologies being developed right now, and it has hundreds of promising applications – from new cancer treatments to improved military machinery to stain-resistant pants," . . . "As these products are developed and used, we must understand any potential risks to human health, safety or the environment. My legislation will help ensure public safety and confidence in the marketplace, and it will support companies that employ nanotechnology materials. (para. 1)

Benjamin Cardin added, "Nanotechnology touches so many facets of our lives today and will play a greater role in the future, but the benefits to industry and consumers come with unknown risks that must be identified and managed appropriately" (Pryor, 2010, para. 3).

A 2011 report entitled *EPA Needs to Manage Nanomaterial Risks More Effectively* provided concerns of industries that produce nanomaterials. The EPA concluded:

> EPA does not currently have sufficient information or processes to effectively manage the human health and environmental risks of nanomaterials. EPA has the statutory authority to regulate nanomaterials, but currently lacks the environmental and human health exposure and toxicological data to do so effectively (U.S. Environmental Protection Agency, 2011, p. 3).

According to this EPA report, there is evidence that agencies that are involved in nanotechnology in the United States are still behind in establishing Environmental, Health, and Safety (EHS) standards.

Regarding the global perspective, the European Commission (2012) is well ahead of the United States in addressing EHS issues of nanotechnology to devise an integrated approach to be safe and responsive toward EMNs. The European Parliament demanded a framework to establish regulations for (1) reviewing and adapting EU laws, (2) monitoring safety issues, and (3) engaging in dialogue with national authorities, stakeholders, and citizens. The European Commission favors the development of nanotechnology; however, safety behavioral, and ethical responsibility should be paramount.

China is behind Europe and the United States on safely handling nanomaterials. China has been focused on the biological and environmental effects of manufactured EMNs (Zhao, Zhao, & Wang, 2008). According to Jarvis and Richmond (2010), some generational gaps (e.g., Baby Boomer, Generation X, & Generation Y) exist among researchers on how to approach EHS difficulties of nanomaterials. This can be a serious problem in the future in terms of worker safety and perhaps increased illnesses and deaths in the workplace.

The National Nanotechnology Initiative (NNI) (2010) conducted a study on Chinese nanotechnology. The NNI concluded that scientific gaps are evident, which include little data to support workers' exposure to nanoparticles/nanomaterials at the worksite. Also, workers who have been examined had been exposed for long as 13 months. China has not created sufficient and suitable industrial hygiene practices to protect workers; to exacerbate the problem peasants were employed at the worksite that did not have any formal training in industrial hygiene or knowledge of the toxicity effects of the nanoparticles/nanomaterials at the worksite.

The Next Step

Unlike general safety training programs, such as HAZWOPER (safety training for the micron world), the nano world is very different, and content must be designed so that workers can understand the environmental, health, and safety hazards of manufactured materials below the 100nm realm. In the semiconductor industry, workers design products in the micro realm. In this area, safety practices have been established for over 30 years. Safety awareness at the nanolevel is mind-boggling, and it is complicated to imagine workers developing materials that are far beyond the naked eye. Opening up a new arena in which industry, researchers, and government agencies have barely scratched the surface dealing with the EHS issues, will be a monumental challenge.

The lead university (Rice University), Texas State University, and the University of Texas at Tyler collaborated to receive funding for the country's first OSHA grant addressing the training needs of safely handling nanomaterials in the workplace. The grant addressed the critical and urgent need for rigorous, science-based, and comprehensive training materials to directly address the safe handling of nanomaterials. There are best practices (CDC, 2012; OSHA, 2012; Good Nano Guide, 2011) for safely handling nanomaterials published on websites. However, no empirical studies have addressed perceptions and effectiveness of training workers on nanotechnology safety.

Training Content Development

The development of the training package is derived from the brightest minds in nanotechnology safety as represented by organizations such as the Center for Biological and Environmental Nanotechnology (CBEN)—Rice University, The Lippy Group, Texas State University, The University of Texas—Health and Science Center at Houston, and the International Chemical Workers Union. Internal and external advisory boards were formed to ensure the topics were taught and input was provided for program improvement.

The training program consisted of establishing an eight-hour course to cover ENM occupational health and safety issues to emphasize human exposure. Seven topics were used to develop the modules. See Figure 1 for illustration. Two trainers went to four locations, including Puerto Rico, to conduct the training. A research study was conducted to ascertain both if learning outcomes were achieved and participants' perspectives on the program.

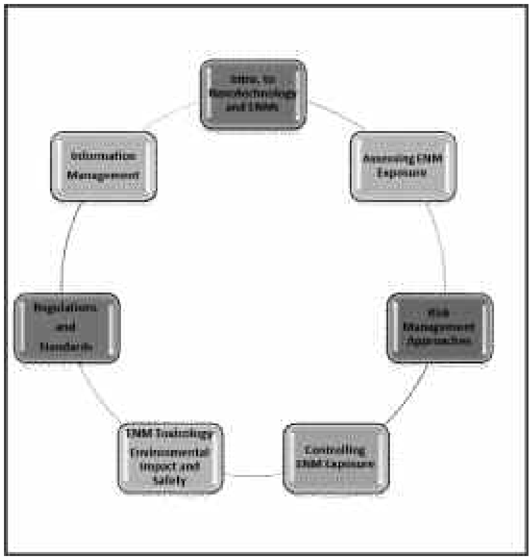

Figure 1. Seven modules used for training program funded by OSHA-Susan Harwood

Purpose of Study

The purpose of this study was twofold: (1) determine if the participants successfully completed the seven topics and (2) determine the participants' perspectives of the program. To ascertain the success of the program, research questions and hypothesis statements were developed.

Research Questions

1. What were the participants' *Cohort 2011* perceptions on the Nanotechnology Safety Training?

2. Was there a difference between the participants' *Cohort 2011* mean scores on the pretest and posttest?

The hypotheses statements that follow are at a .05 alpha level for research question 1. The alpha level of .05 is commonly used in education because of the likelihood of making Type I and Type II errors.

Hypothesis Statement

1. Ho: There is no difference between the participants' mean scores on the pretest and posttest.

   Ha: There is a difference between the participants' mean scores on the pretest and posttest.

Methodology

Research Design

The research design for hypothesis statement 1 employs a minimal control, one-group, pretest-posttest design (Campbell & Stanley, 1966). Even though there can be a significant result from the design, there are disadvantages. For example, there is no assurance that the treatment (training material) will be the only major factor in participants' learning.

Research question two uses a survey research (descriptive) design to obtain the participants' perspectives. According to Isaac and Michael (1997), this research method is used "to describe systematically a situation or area of interest factually and accurately" (p. 46).

Statistical Analyses Used

The study utilized descriptive analysis and a paired samples t-test. The rationale for the descriptive analysis was to collect the frequency of the participants' perception based on the 4-point Likert scale. The paired samples t-test was used to determine if there was an increase in the group-mean scores from the pretest to posttest.

Population of Participants

The nanotechnology safety training targeted small- to medium-sized ENM fabrication plants, processing companies, and research facilities. There are many small- to medium-sized companies that have no (or few) dedicated safety professionals on staff; instead, in such companies an engineer or a scientist (if anyone at all) may be tasked with health and safety duties as an adjunct to that staff member's primary responsibilities. A worker who fulfills such a dual role must find and apply reliable information about the safe handling of ENMs so that he or can disseminate critical information within a facility. Even when a trained safety professional is on staff, the worker will likely have had little prior experience specifically with ENMs and would benefit from learning how to apply his or her existing professional knowledge to this new class of materials.

Flyers were used for each site to invite workers to receive training. Tables 1a and 1b illustrate the training sites and number of attendees for 2011.

Table 1a: Training Locations

Training Location	City-State/Territory
Mission College	Santa Clara, CA
Univ. of Cincinnati	Cincinnati, OH
Labor College	Silver Spring, MD
University of Puerto Rico	Puerto Rico

Table 1b: Number of Participants by Training Location

Training Location	No. of Attendees #
Mission College	11
Univ. of Cincinnati	37
Labor College	25
University of Puerto Rico	30

\# *n* = 103

There was a wide range of participants, differentiated by job title and level of education, who attended the training sessions for 2011. See Tables 2a and 2b.

Table 2a: Number of Participants by Job Title

Job Title	No. of Attendees*
Environmental Health	3
Injury and Prevention Control	1
Occupational Safety	25
Occupational Health Nursing	1
Occupational Medicine	4
Industrial Hygiene	23
Other	

* Note: The number of attendees from the Table 2a does not reflect the number of attendees in Table 1b. There were some people who dropped out or left early.

Instruments for Study

The instruments for the study were a pretest, posttest, and end-of-the-course survey. The pretest consisted of 14 questions (5 true/false), and 9 short-answer questions). The

Table 2b: Number of Participants by Level of Education

Education Level	No. of Attendees*
High School	5
Some College	13
Associate Degree	2
Bachelor of Arts or Science	30
MS/MA/MPH	7
Doctorate	44

* Note: The number of attendees from the Table 2a does not reflect the number of attendees in Table 1b. There were some people who dropped out or left early.

posttest contained the same number of questions; however, the questions were reworded and ordered differently. The end-of-the-course survey contained three sections (demographic, rate the instructors, and course experience), for a total of 15 questions. There were14 statements with a 4-point Likert-type scale (Excellent, Good, Fair, and Poor). Cronbach's alpha was performed by Statistical Package for the Social Sciences (SPSS) to test for reliability of the survey instrument. There was a reliability of .721, which is considered acceptable. Face validity was conducted by the internal and external advisory panel to assess whether or not the questions were appropriate to evaluate the participants in the training program.

To prevent internal threat to validity, the posttest questions were rearranged and reworded slightly from the pretest. The instruments were developed to address assessment needs for reporting to OSHA.

Data Collection Procedures

The data from the pretests, posttests, and end-of-the-course evaluations were collected at the end of the training sessions for each site. Data were collected and stored on Excel spreadsheets. Steps were taken to ensure the pretests and posttests score were matched by participant. The data were imported to SPSS to generate results.

Results

Survey Results

The results are displayed in this section for the research questions. The SPSS-Crosstab function was used to generate frequencies by the 4-point Likert-type scale for each statement that was answered by the participants. The research question stated, *What were the participants' (Cohort 2011) perceptions of the Nanotechnology Safety Training?* Tables 3-5 addressed the quality of the course by each training site. Participants at the training sites—Santa Clara, University of Cincinnati, Labor College, and University of Puerto Rico believed that the content suited their requirements. See Table 3.

Participants at the training sites (Santa Clara, Univ. of Cincinnati, Labor College, and Univ. of Puerto Rico) responded good to excellent that the topics were covered in detail. See table 4.

Table 5 illustrates the majority of the participants at each training site rated the nanotechnology safety course was good to excellent.

Table 3. Was the content suited to your requirements?

$n = 103$

	Likert-Type Scale				
Training Site	**Fair**	**Good**	**Excellent**	**Not Answered**	**Total**
Santa Clara	1	5	4	1	11
University of Cincinnati	3	18	16	0	37
Labor College	4	17	4	0	25
Univ. of Puerto Rico	4	12	14	0	30

Table 4. Were the topics covered in sufficient detail?

$n = 103$

	Likert-Type Scale				
Training Site	**Fair**	**Good**	**Excellent**	**Not Answered**	**Total**
Santa Clara	0	8	3	0	11
University of Cincinnati	5	16	15	1	37
Labor College	0	13	12	0	25
Univ. of Puerto Rico	3	14	13	0	30

Table 5. Overall rating of the course follows:

$n = 103$

Likert-Type Scale					
Training Site	**Fair**	**Good**	**Excellent**	**Not Answered**	**Total**
Santa Clara	0	6	5	0	11
University of Cincinnati	1	16	20	0	37
Labor College	1	10	12	2	25
Univ. of Puerto Rico	1	13	16	0	30

Table 6. Instructors have the ability to provide real world experience.

$n = 103$

Likert-Type Scale				
Training Site	**Fair**	**Good**	**Excellent**	**Total**
Santa Clara	0	5	6	11
University of Cincinnati	5	15	17	37
Labor College	2	3	20	25
Univ. of Puerto Rico	1	10	19	30

Table 7. Instructors have knowledge of the subject matter.

$n = 103$

Likert-Type Scale			
Training Site	**Good**	**Excellent**	**Total**
Santa Clara	2	9	11
University of Cincinnati	7	30	37
Labor College	2	23	25
Univ. of Puerto Rico	7	23	30

Table 8. Instructors' presentation abilities were . . .

$n = 103$

Likert-Type Scale					
Training Site	**Fair**	**Good**	**Excellent**	**Not Answered**	**Total**
Santa Clara	0	1	9	1	11
University of Cincinnati	1	14	22	0	37
Labor College	0	8	17	0	25
Univ. of Puerto Rico	1	4	25	0	30

Table 9. Overall rating of the instructors . . .

$n = 103$

Likert-Type Scale				
Training Site	**Fair**	**Good**	**Excellent**	**Total**
Santa Clara	0	1	10	11
University of Cincinnati	1	7	29	37
Labor College	2	4	21	25
Univ. of Puerto Rico	1	5	25	30

Table 10. Materials, handouts, and activities useful . . .

$n = 103$

Likert-Type Scale				
Training Site	**Fair**	**Good**	**Excellent**	**Total**
Santa Clara	0	7	4	11
University of Cincinnati	4	13	20	37
Labor College	1	12	12	25
Univ. of Puerto Rico	1	13	16	30

The next tables address the quality of the instructors and materials by each training site. See Tables 6 through 11. In all training sites for Table 6, participants believed the instructors did a good to excellent job providing real-world experience for safely handling nanoscaled materials. The majority participants in the training program indicated the instructors provided real-world experience to the course. See table 6.

The participants at the training sites rated the instructors' knowledge of nanotechnology safety from good to excellent. See table 7.

In Table 8, participants who completed the survey rated the instructors' abilities to present the material as good to excellent. See Table 8.

The majority of participants at the training sites rated the instructors as excellent for delivering the training materials. See Table 9.

The participants perceived the materials, handouts, and activities were useful for the training course. See Table 10.

In Table 11, all participants from the training sites rated the quality of the overall materials from good to excellent.

Tables 12-14 illustrate the importance of having nanosafety certification at the worksite.

All participants who answered the survey question agreed that they would consider being certified.

About 50% of the participants at the training sites would consider being certified in nanotechnology safety. See Table 12.

Three out of four training sites agreed that certification would be valuable to the participant and to the employer. University of Cincinnati was split on whether nanotechnology safety certification would be valuable to the company as well as for the individual. See Table 13.

All four of the training sites agreed or strongly agreed that certification in nanosafety is important to the field. Ten participants from

Table 11. Overall quality of the training materials

n = 103

	Likert-Type Scale				
Training Site	**Fair**	**Good**	**Excellent**	**Not Answered**	**Total**
Santa Clara	0	6	5	0	11
University of Cincinnati	0	16	19	2	37
Labor College	0	13	12	0	25
Univ. of Puerto Rico	1	8	20	1	30

Table 12. After this training, would you consider becoming certified in nanosafety?

n = 97*

	Decision Type			
Training Site	**Yes**	**No**	**Do not know**	**Total**
Santa Clara	9	0	1	10
University of Cincinnati	20	15	1	36
Labor College	10	11	0	21
Univ. of Puerto Rico	26	4	0	30

*Note: Six participants did not answer.

Table 13. Would certification in nanotechnology safety be valuable to you and your employer?

n = 96*

	Decision Type			
Training Site	**Yes**	**No**	**Do not know**	**Total**
Santa Clara	10	0	0	10
University of Cincinnati	18	15	3	36
Labor College	17	8	0	25
Univ. of Puerto Rico	25	0	0	25

*Note: Seven participants did not answer.

Table 14. Certification in nanotechnology safety is important to the field.
n = 96*

	Likert-Type Scale					
Training Site	**strongly disagree**	**disagree**	**neutral**	**agree**	**strongly agree**	**Total**
Santa Clara	0	0	1	7	2	10
University of Cincinnati	1	2	8	16	8	35
Labor College	0	0	0	11	10	21
Univ. of Puerto Rico	0	0	0	30	0	30

*Note: Seven participants did not answer.

Labor College agreed strongly that to obtain certification is important. See Table 14.

To determine effectiveness of the course training, a paired-samples t-test was used. The paired-samples t-test requires a sample size of 30+ (Pallant, 2005), which was adequate for answering the hypothesis statement. The material taught at each training site was identical and grouped as Cohort 2011 to achieve the necessary sample size. Ninety-eight participants completed the pretest and posttest. Determining significance for each training site was not possible because of the unequal sizes of the enrollment. To verify the SPSS output was valid, assumptions were checked to determine if there were any violations. There were no violations in the assumptions.

The paired-samples t-test was conducted to determine the course effectiveness—if there was an increase of the mean group score of the participants from the pretest to posttest based on the training material taught. There was a statistically significant increase in the posttest scores from the pretest ($M = 7.939$, $SD = 5.9327$) to the posttest [$M = 15.571$, $SD = 4.7883$, $t (98) = -13.482$, $p < .0005$]. Therefore, the null hypothesis was rejected and the alternative accepted.

Conclusion and Discussion

The study concluded with positive results for the training program. According to the posttest scores, there was a significant improvement in the participants' knowledge of nanosafety. Even though the participants started at different levels from the pretest, the variation of improvement on the posttest was about even across the training sites. Testing the hypotheses to determine whether there was a significant change in the pretest and posttest group mean score was based on the effectiveness of the training. The study also revealed a statistically significant difference in the pretest and posttest group mean score, which meant that the training material was effective and contributed to the improvement in the posttest scores. The authors suggest that readers approach the findings with caution. The significance of the study is only generalized to the four training sites. One must conclude that there were uncontrollable external variables (i.e., monetary incentives, self-motivation), which may have contributed to the increase of the mean group score of the posttest.

In Tables 13 and 14, the participants believed that nanotechnology safety training is important for the viability of companies who manufacture nanomaterials. Thus, in Table 12, participants agreed that certification would be important to the participants. Agencies like NIOSH, OSHA, and professional organizations—ATMAE, IEEE, ASSE, and others—could pave the way to developing certification. ATMAE has a certification division with four certification exams already developed and in use. As ATMAE expands the organization for new skill sets to continue to meet industries' demands, the organization can be a support mechanism to assist in implementing nanotechnology safety courses. To make this certification a reality, more collaboration is needed among government agencies, industries, and other professional organizations to create a valid and comprehensive nanotechnology safety certification.

The funded grant on training workers in nanotechnology safety is groundbreaking and a catalyst to make educators and government agencies aware of the importance of nanotechnology safety training. As more ENMs are created, industry must become more cognizant of the training needs of the workers. Constant improvement of training materials from research and industry practice will be vital to the field of nanotechnology. A workforce that is well trained in safely handling nanoscale materials will lessen the likelihood of catastrophes and decrease public skepticism. Training materials on nanosafety will become available to the public soon on the OSHA website; however, The Good Nano Guide has similar materials, which are available to the public.

Dr. Dominick E. Fazarro is an Associate Professor in the Department of Human Resource Development and Technology at The University of Texas at Tyler. He is a Member-At-Large of Epsilon Pi Tau.

Dr. Walt Trybula is a Senior Researcher at Ingram School of Engineering at Texas State University, San Marcos.

References

Campbell, D. T., & Stanley, J. C. (1966). *Experimental and quasi-experimental designs for research.* Chicago, IL: Rand McNally & Co.

Center for Disease Control and Prevention (CDC) (2012). *Worker safety & health topics-nanotechnology*. Retrieved from http://www.cdc.gov/niosh/topics/nanotech/

European Commission (2012). *Public Health.* Retrieved from http://ec.europa.eu/health/nanotechnology/policy/index_en.htm

Fazarro, D., & Trybula, W. (2011, August). *Empowering academia to look into the future: Nanotechnology safety education-creating the workforce that you will need.* Paper session presented at the meeting of IEEE NANO 2011 Conference, Portland, Oregon.

Good Nano Guide (2011). Retrieved from http://www.goodnanoguide.org/tiki-index.php?page=HomePage

Isaac, S., & Michael, W. (1997). *Handbook in research and evaluation: For education and the behavioral sciences* (3rd ed.). San Diego, CA: EdITS/Educational and Industrial Testing Services.

Jarvis, D., & Richmond, N. (April, 2010). *Mapping emerging nanotechnology policies and regulations: The case of the People's Republic of China.* Paper presented at the Lee Kuan Yew School of Public Policy-Working Paper Series, Singapore.

Maynard, A. (2010, February 18). *US government kicks nanotechnology safety research up a gear. 2020 Science: A clear perspective on emerging science and technology.* Retrieved from http://2020science.org/2010/02/18/us-government-kicks-nanotechnology-safety-research-up-a-gear/

Nanocyl (2009). *What is a nanocarbon tube?* Retrieved from http://www.nanocyl.com/CNT-Expertise-Centre/Carbon-Nanotubes

Nanoparticle Task Force ACOEM (2011). Nanotechnology and health. *Journal of Occupational & Environmental Medicine, 53*(6), 687-689.

National Nanotechnology Initiative (NNI) (2009). *Nanotechnology: Big things from a tiny world* Retrieved from http://www.nano.gov/html/society/ Educations.html

National Nanotechnology Initiative (NNI) (2010). *Chinese nanotechnology study: Fact sheet.* Retrieve from http://www.nano.gov/node/162

Occupational Safety & Health Administration (OSHA) (2012). *Nanotechnology safety standards.* Retrieve from http://www.osha.gov/dsg/nanotechnology /nanotech_standards.html

Pallant, J. (2005). *SPSS survival manual* (2nd ed.). Chicago: SPSS, Inc.

Pryor, M. (2010, January 21). Pryor, Cardin call for increased research to ensure product *safety* cite Arkansas facility and Maryland HQ as ideal locations for nanotechnology studies [Press Release]. Retrieve from http://www.pryor.senate.gov/public/v index.cfm?p=PressReleases&ContentRecord_id=92f252e2-7d7c-453d-8be8-f80c3f764ec8

Roco, M. (2001). International strategy for nanotechnology research and development. *Journal of Nanoparticle Research, 3* (5-6), 353-360.

Roco , M. C. (2003). Converging science and technology at the nanoscale: Opportunities for education and training. *Nature Biotechnology, 21*(10), 1247-28. doi:1016/S0958-1669 (03)00068-5

Shatkin, J., Abbott, L. C., Bradley, A. E., Canady, R. A., Guidotti, T., Kulinowski, K. M., Williams, M. (2010). Nano risk analysis: Advancing the science for nanomaterials risk management. *Risk Analysis, 11* (30), 1680-1687.

Takagi, A., Hirose, A., Nishimura, T. (2008). Induction of mesothelioma in p53+/- mouse by intraperitoneal application of multi-wall carbon nanotube. *Journal of Toxicological Sciences 33*(1), 105-116.

Trybula, W., Fazarro, D., & Kornegay, A. (2009). The emergence of nanotechnology: Establishing the new 21st century workforce. *The Online Journal for Workforce Education and Development, 4* (3), 1-10. Retrieved from http://wed.siu.edu/Journal/ VolIIInum4/Article_6.pdf

U.S. Environmental Protection Agency-Office of Inspector General. (2011). *Needs to manage EPA nanomaterial risks more effectively* (EPA Publication No. 12-P-0162). Retrieved from http://www.nanolawreport.com/uploads/file/EPA%20Needs%20to%20 Manage%20Nanomaterial%20Risks%20More%20Effectively.pdf

Wedin, R. (2006). Is nanotechnology safe? Retrieved from http://www.wedincommunications.com/Chemistry%20Nanotech%20Spring06.pdf

Zhao, F., Zhao, Yuliang, & Wang, C. (2008). Activities related to health, environmental and societal aspects of nanotechnology in China. *Journal of Cleaner Production, 16*, 1001-1002.

Developing Occupational Programs: A Case Study of Community Colleges

Duane E. Doyle

Abstract

A progressively more technological and competitive employment environment in today's world economy requires employees to have a firm understanding of critical technical skills to build on when they arrive at the workplace. This study examines how differences in the environmental conditions and organizational factors facing four community colleges contributed to the development of occupational and technical education programs.

This study was driven by one primary research question: What environmental conditions and organizational factors influence the nature of the strategic response in the form of technical education program development within community colleges? To answer this question, a qualitative study of both stakeholders in higher education (which included individuals at four community colleges in the state of Arkansas) and individuals at the Arkansas Department of Higher Education was conducted. The institutions selected represented the widest possible range of organizations.

A conceptual framework was developed that included previous research on normative, regulative, and cultural-cognitive environments and organizational response processes. The framework served as a guide to identify how external conditions in these processes influence the nature of the development of occupational and technical education programs at community colleges in Arkansas.

Key Words: Program Development, Occupational Education, Technical Education, Case Study, Environmental Response, Organizational Theory

Introduction

Recent decades have witnessed a growing discrepancy in the income of workers with different levels of education. Individuals with high school diplomas or less education saw their earning potential fall throughout much of the 1980s and 1990s compared with those who had more education. Between the years 1979 and 2005, real hourly wages rose for college graduates by 22%; for high school graduates they remained stagnant, and for high school dropouts, wages fell by 16% (Mishel, Bernstein, & Allegretto, 2005). Fewer than 50% of low-income workers, had more than a high school degree in 2003, and about 20% percent of these were high school dropouts (Acs & Nichols, 2007).

Even before the recent recession people who had minimal skills landed few jobs offering any noteworthy or lasting wage increases over time, fundamentally because they lacked the basic skills and education needed to advance. In a 2005 study, Anderson, Holzer, and Lane found that although low-wage earners experienced some gains in earnings over time, no more than one quarter of them permanently escaped their low-wage status. Several low-skill workers also did not have access to employment opportunities with potential for career progression, particularly in the higher wage segments of the economy, such as health care or manufacturing. The current economic crisis brings a new urgency to these labor market challenges, particularly for the low-skilled individuals competing for a shrinking number of jobs (Anderson, Holzer, &Lane, 2005).

Various experts subscribe to the notion that the severe recession that began in 2008 was the worst since the Great Depression of the early twentieth century. While this situation has had a negative effect on all social classes, it is especially grave for the lesser educated and the lower skilled job holders. Many of these low-skill jobs will not return, because of the transformation of both the American and the global economy (Friedman, 2005). One example of such restructuring is presented in the case of General Motors, where the bankruptcy and restructuring could cause the downsizing of the company by some estimates as much as 90% from its employment levels of the 1970s (Lasic & Bunkley, 2009).

The demand for highly trained and skilled labor is rising in the United States and the world, while the need for low-wage, low-skilled workers is in decline. One example is the trend for U.S. businesses to outsource the manufacturing of their products to low-wage countries (Gordon, 2005). Such outsourcing allows businesses to maximize their profits. According to the report *America's Forgotten Middle-Skill Jobs* (Holzer & Lerman, 2007), middle-skill jobs still make up approximately half of all employment today. In this report, the author defines middle-skill jobs as those that involve some noteworthy education and training beyond high school but less than a bachelor's degree.

The requirement for America to have more citizens with the technical skills and knowledge who will participate effectively in the workforce of the 21st century is becoming more evident. As a part of this need for a skilled and trained workforce, there is also the need for the workers to have access to skilled jobs. Warren (2000) reported when analyzing organizations' manufacturing needs in the United States that an inescapable focus occurs with employee education and training. Implementing new technologies is reliant on the proficiency of the individuals who use them. The capability to respond to rapid changes in world markets depends on workforces that can rapidly assimilate new assignments and roles by acquiring needed skills. When looking for solutions to issues related to training, many corporations have focused their attention on community colleges.

According to the report *America's Forgotten Middle-Skill Jobs* (Holzer & Lerman, 2007), for U.S. workers who do not complete some form of postsecondary education (certificate programs, associate's, bachelor's, graduate, and professional degrees) opportunities will become increasingly limited. Even more persuasive, however, is that occupations which previously required only a high school diploma now require levels of technical skills and knowledge that dictate advanced and continuing education. Students who continue their education beyond high school should realize clear economic benefits (National Center Education Statistics, 2001). The U.S. Bureau of Labor Statistics reported that in 2011 employees who did not finish high school earned $451 per week, whereas those with a high school diploma earned $638 per week. The Department of Labor also found that in 2011 a person with some college earned $719 per week, a person with an associate's degree earned $768 per week, and a person with a bachelor's degree earned $1,053 per week (U.S. Bureau of Labor Statistics, 2012). The U.S. Bureau of Labor Statistics also reported that the unemployment rate for those who attended college was significantly less than for those who did not. For employees who did not finish high school, the unemployment rate was 14.1%; employees with a high school diploma had an unemployment rate of 9.4%; and employees who had some college had an unemployment rate of 8.7%. The greatest differences occurred at the associate's degree level and the bachelor's degree level, where unemployment was 6.8% and 4.9%, respectively (U.S. Bureau of Labor Statistics, 2012).

Statement of Problem

There is a serious lack of literature to assist college academic managers in the development of career and technical education programs. Numerous peer-reviewed articles exist regarding the many aspects of a career and technical program, but a model does not exist to help the practitioner in the development of the program (Rojewski, 2002). The need for career and technical education was clearly expressed as early as 1964 (Doyle, 2011, p. 6)

According to Grubb (1999, para. 1), "In many ways postsecondary occupational education (PSOE) is a stepchild – even a stepchild of a stepchild. The institutions where it takes place – community colleges, technical institutes, some area vocational schools, other public training centers, private proprietary schools – are not well known and are often low status." Grubb declared that "in federal policy, these institutions are often afterthoughts: they do not benefit from the large programs aimed at K-12 schooling; and federal aid for vocational education, one of the few federal programs providing funding to both secondary and postsecondary programs, has always been written with secondary education in mind" (1999, para.1). Rojewski (2002) reported the need for the educational system to prepare workers for entry-level employment in the careers in the current labor market. Rojewski also expressed the need to focus federal funds on high schools and community colleges to be able to assist populations that are less likely to succeed in the labor force.

Research Question

The principal research question that directed this inquiry was:

What environmental conditions and organizational factors influence the nature of the strategic response in the form of technical education program development within community colleges?

To answer this overarching question five main subareas were developed:

- How are technical education programs developed in community colleges? How does the technical education development process differ within different community colleges? How does the technical education development process differ by the type of technical program being developed?
- How do differences in societal conditions; federal, state, and local governmental requirements; governing board requirements; and administrative actions in the regulative dimension influence the development of an institutional response in the form of technical education programs?
- How do the differences in program philosophy, public expectations, accrediting agency requirements, and student populations in the normative dimension influence the development of an institutional response in the form of technical education programs?
- How do the differences in the curriculum, instructional delivery, and student learning in the cultural-cognitive dimension influence the development of an institutional response in the form of technical education program?
- How do pressures that cause strategic responses, including the need for acquiescence, compromise, avoidance, defiance, and manipulation influence the development of an institutional response in the form of technical education program?

Conceptual Framework

The conceptual framework was derived from a review of the pertinent literature and was influenced by the work of Rojewski (2002). Rojewski's work, used as a basis, is intended as a jumping-off point. It suggests several dimensions that influence the environment of technical education development. Essentially, these dimensions of inspiration were examined according to resource dependency and institutional theories that envisage the nature of the processes, relationships, and environmental interactions (both external and internal) that embody the technical education development process.

The conceptual framework was then placed into an institutional theory framework. The context for this piece of the framework was addressed by Scott (2001) and Oliver (1991) and was used to refine this conceptual framework. The three institutional pillars: regulative, normative, and cognitive (Scott, 2001) and strategic responses (Oliver, 1991) were critical to the development of the conceptual framework. Focusing this study in this manner enables the researcher to build a case study that will spotlight the why and how things happen more than just if they happen. It will take advantage of the strengths of qualitative research methods to explore the data in a richer, more precise fashion.

The regulative pillar was defined by Scott (2001) as the overt regulative processes, for example, rule setting, monitoring, and sanctioning. It also includes the ability to institute rules, scrutinize or review others' compliance to them, and as needed, direct sanctions in terms of both rewards and punishment to sway future behavior. These processes may operate through informal means, for example, shaming and shunning activities, or the processes may be more formalized for example, through the police or courts.

The normative pillar is characterized by placing emphasis on normative rules that introduce a narrow, evaluative, and essential dimension into social life. Normative systems include both values and norms. Values are models of the ideal or the desirable together with the interpretation of standards to which existing structures or behavior can be compared and assessed. Norms specify how things should be done. Norms identify how things should be done and describe legitimate means to pursue valued ends. This pillar defines goals and objectives and the best way to pursue them (Scott, 2001).

The cognitive pillar emphasizes the importance of cognitive elements for institutions and the rules that compose the nature of reality and the structure through which meaning is made. Symbols (e.g., words, signs, and gestures) have an effect by shaping the meaning attributed to objects and activities (Scott, 2001).

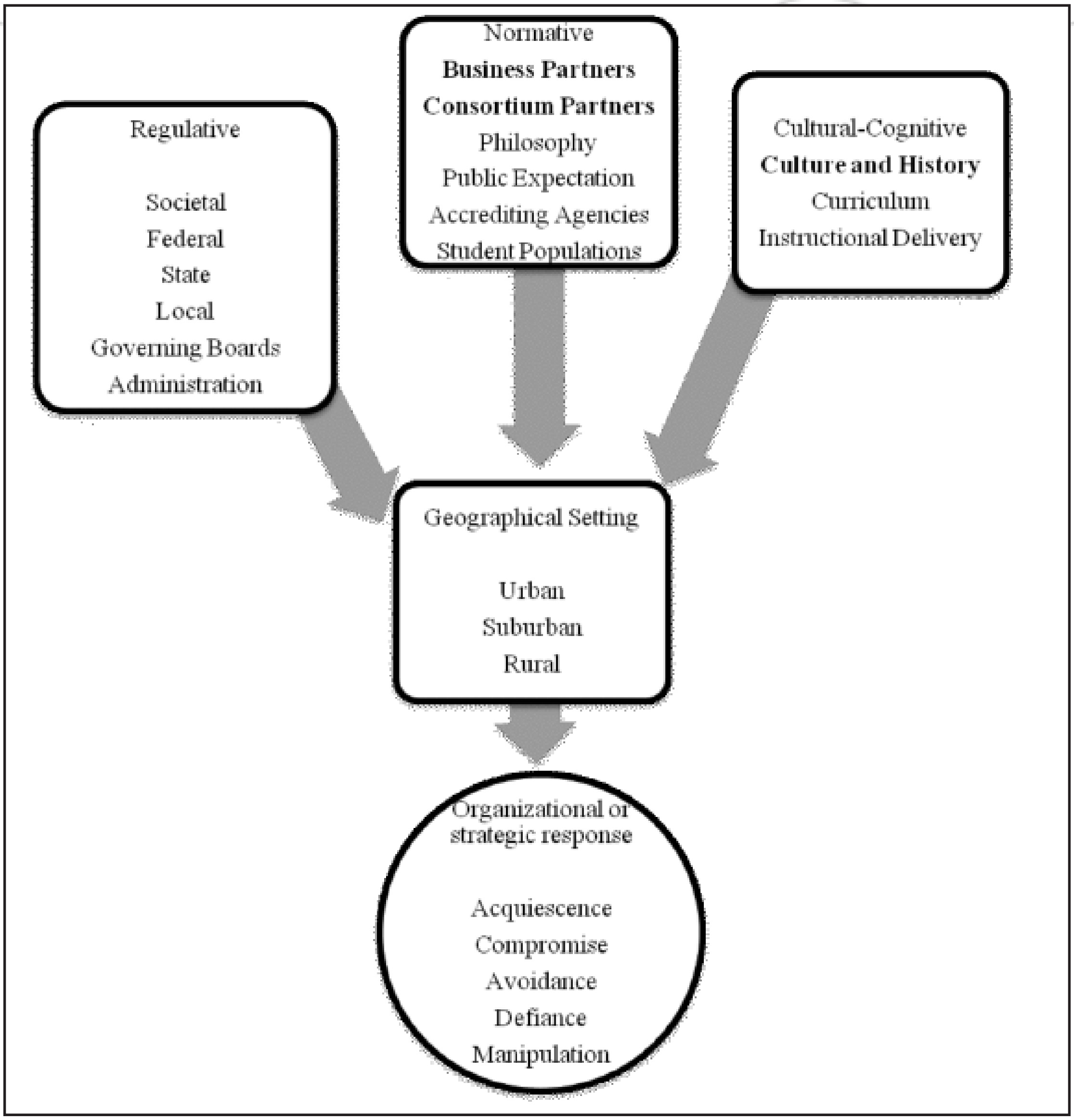

Figure 1. Revised Conceptual Framwork Guiding the Study of four Arkansas Community Colleges (Adapted from Rojewski, 2002 and Scott, 2001)

Method

The basis for this research was to examine the development of career and technical education programs in a community college using a qualitative case study approach. The conceptual framework was derived through a review of the literature, and it serves to focus and direct this study. The aim of the research is to assist decision makers in understanding both how Career and Technical Education (CTE) programs are developed and what makes them work. In order to achieve useful data, the researcher must stress to the participants to give open and honest answers that are more helpful than adulations and to abstain from providing signals of positive acceptance to feedback so that respondents will not be swayed to provide answers that would be perceived as positive.

Summary of the Study

This study was driven by one primary research question: What environmental conditions and organizational factors influence the nature of the strategic response in the form of technical education program development within community colleges? To answer this question, a qualitative study of four community colleges in the state of Arkansas was conducted. The organizations included the University of Arkansas Community College at Hope, Pulaski Technical College, National Park Community College, and Mid South Community College. These institutions, because of their geographical locations and student populations, were selected to represent the widest possible range of institutions.

A conceptual framework was developed that encompassed previous research on normative, regulative, and cultural-cognitive environments and organizational response processes. The framework, adapted from Rojewski (2002) and Scott (2001), served as a guide to identify how external conditions in the normative, regulative, and cultural-cognitive environments and organizational responses differently influence the nature of the development of programs.

Data were collected by interviews of administrators, division chairs, and instructors of technical programs from April 2010 to June 2010. Twenty-two individuals were interviewed. The interviews were recorded digitally, transcribed verbatim, and coded for analysis using the variables on normative, regulative, and cultural-cognitive environments and organizational responses from the conceptual framework. Documents and other archival data were used in combination with the interview data to describe and explain the factors that influence the occupational program development in the colleges.

Table 1. Participants of the study

Title	Participants
Vice-President or Vice Chancellor of Academics	4
Dean or Division Chair	6
Instructor	12

Review of Findings

This study presents a primary effort to scrutinize a key element in the occupational program development to determine how external conditions and internal organizational characteristics cooperate and combine to influence the nature of organizational response that manifests itself in the process of technical program development. Tentative evidence suggests that program development examined through the institutional response filters is a useful framework for explaining the development of technical programs. It also indicates that organizational characteristics play a fundamental part in the nature of the development of occupational programs.

Regulative Factors

Regulative factors play a major role in the development of all programs, including occupational programs. Each of these variables has a direct relationship with the institution and how the programs are developed. Some of these relationships are direct and some are consequential. For example, in most case study institutions, the administration involves students, faculty, staff, community members, and many others when developing the institutional strategic plans. From the strategic plans, the administration makes priorities for the institution and puts forth directives that program developers must follow.

The regulative variable the participants mentioned as having the most direct influence on the development of technical programs is the administration. The administration makes priorities for the institution, and it is the information exchange for most business and industry leaders. The priorities set by the administration provide resources, such as money to buy supplies or equipment, and employees to be able to work the program. From these priorities also spring many real properties like buildings, offices, classrooms, and laboratory space available for program use.

Each of the case study institution participants mentioned another major direct influence to occupational program development, the state government. The state governor meets with potential businesses and industries that want to locate within the state. These discussions can provide the institution with possible resources through the legislative system of the state. Another direct influence from the state government comes from the Arkansas Department of Higher Education (2005, p. 12). This Department initially influences a program through the guidelines it has established for the approval of a program. More directly, the Arkansas Department of Higher Education also influences development stages through the approval process, and if this Department wants to change a program, the program developer is asked to consider a change before it will be approved and the institution is allowed to offer the degree (Arkansas Department of Higher Education, 2005, p. 14).

The participants declared the variable with the most indirect influence is the federal government. Although the federal government provides some direct regulations or policies, most if its influence is provided in an indirect way in the form of money either to students or for programs. This influence provides the federal government with a very subtle mechanism to direct both programs and higher education institutions. Most higher education institutions could not survive without the students being able to obtain some federal financial aid. This one fact is paramount in the discussion and development phases of the program.

Normative Factors

The normative factors play a major role in the development of occupational programs. Each of the case study participants had many similar views about the normative factors, but there were interesting differences.

The case study participants listed similar traits when discussing philosophy and accreditation agencies. In the matter of philosophy, each participant mentioned the overarching philosophy of essentialism. In this study, essentialism was defined as a teacher-centered system, where the teacher takes the leadership role and sets the tone for the classroom. This philosophy is strengthened by the inclusion of an advisory committee and the ideas of the committee. Though most of the participants believed that the program should be a blend of all the educational philosophies and include the good traits from each one, they agreed that the main alignment occurred with essentialism.

The accreditation agencies are another variable about which the case study participants have agreed. The participants felt that the required accreditations must be accomplished. The participants thought it was also a good idea for programs to be included in the voluntary accreditation and match the requirements. When a program was built around the requirements of a voluntary accreditation agency, it made the accreditation a smoother process and the application and the subsequent accreditation yields a degree of instant credibility for the program.

The case study participants differed in their opinions of the impact of public expectations. The perception about the influence of public expectation ran the gamut between having very little influence on the development of a program and having an intense influence on the development of occupational programs and should be included in the model of occupational development.

Another disagreement occurred with the factor about the projected student population. Some of the participants believed that the projected student population played almost no role in deciding whether or not to develop a technical program. These participants thought it was incumbent upon the administration and the faculty, once the program was developed, to advise students how to get started in the program and how to handle any developmental course the student might need. Other participants mentioned the projected student populations did influence the development of occupational programs because to attract diverse students takes planning for their needs.

Cultural-Cognitive Factors

The case study participants held similar thoughts about the cultural-cognitive factors, especially the variable instructional delivery. Instructional delivery turned out almost unanimously in the response because the participants all mentioned that it was best to start a program in a classroom and get a glimpse how the program works as the faculty works through the curriculum with students in a classroom. This live teaching opportunity allows a faculty member to adapt the program to the students at hand, and it will provide important data to enable the faculty to provide the coursework in other media.

Although the participants agreed on the need for some basic curriculum subjects, they did not agree on how the student should receive those subjects. In some cases the research participant suggested that subjects like mathematics, English, or sociology should be contextualized in the technical coursework. Others suggested that these subjects should be taken from the college's normal array of courses, and the technical students should be a part of the typical college experience. For example, the mathematics requirement for all other programs is college algebra, and so the technical programs should also require it. During the interviews the majority of the participants mentioned that the curriculum for the program should include subjects that would enable students to further their degree plans and not be a hindrance to them. Most research participants felt that students who decided to continue their education should not be penalized by taking general education courses that would have to be repeated because these did not fulfill the degree requirements of future undergraduate degrees.

Findings

In addition to the basic findings of the conceptual framework, some additional issues emerged that have implications for program developers and other stakeholders. One significant finding related to the normative dimension is the population located around the college. The more urban the setting, the easier it becomes to develop and offer programs. The larger the population center the college is situated in, the larger the prospective pool of students that helps to bolster the requisite numbers to support the program. This finding illustrates the disparity between programs that are started in large population centers and those begun in smaller areas. This finding illustrates that rural and even suburban colleges can have difficulties with some programs finding requisite numbers of students that are needed and necessary for viability, but an urban college may not have trouble with attracting them.

Also a variable in the conceptual dimension geographic setting is college density. College density is the saturation of similar college degrees in a given geographical area (Doyle, 2011). This is exemplified by the city of Little Rock. The metropolitan area includes Little Rock, North Little Rock, Sherwood, Jacksonville, and Maumelle. There are over 583,845 people in the Little Rock area. The public colleges for Little Rock include Pulaski Technical College, University of Arkansas at Little Rock, and University of Arkansas Medical Sciences. The private colleges in Little Rock include Arkansas Baptist College, Philander Smith College, Remington College, and Webster University. This list does not include the numerous online colleges. This list yields four private colleges, three public colleges, a host of online colleges, and a multitude of specialty schools (e.g., beauty colleges, barber schools and many specialty trade schools). While there are several opportunities for students to attend postsecondary institutions, the overall college density is light. The result of this college density is a significant student enrollment over the last several years in beginning-level courses.

Program duplication is a dimension within college density. The term program duplication can be defined as saturation of similar competing college degree programs in a given geographical area. This competition would include a nursing program that awarded a diploma from an educational hospital, and a one-year practical nursing program at the local community college where a technical certificate was awarded.

A finding related to the normative dimension is the strength of a program when a business or industry partner is involved. Each partner adds a part to the program and helps the program to develop in a unique manner within that location. This kind of relationship with a business partner provides many opportunities for students, and these students spread the word about the outcomes and opportunities that the program afforded them. A program with a strong relationship to a business or one from which graduates are recruited by one industry will be seen as a gateway program to employment, and this helps to promote the program.

The addition of the variable consortium partners to the normative dimension was needed. The variable consortium partners is defined as the factors that deal with the interaction of the colleges as they work jointly to put career and technical programs together as a collective group. Consortium partners deal with multiple administrations, governing boards, communities (public expectation), and more. This variable also has an added factor in that students will transfer between member institutions, and this movement provides a new element to the relationship because programs must be comparable.

Discussion

During the interviews the participants held some reluctance about assigning characteristics from the strategic response dimension. This reluctance led the investigator to blend terms together to allow the participant a little more comfort with the terms. The terms acquiescence and compromise were seen as the same response just at different levels called negotiation resolution. Most participants viewed these terms as part of the negotiations that an institution goes through. This would define compromise as the working out a plan where both parties receive some benefit from the pact. Acquiescence would be defined as one party weighing the situation and determining the course of action required for this negotiation is to accept the other party's method or plan. The terms avoidance and defiance were also seen as terms within a single variable that could be called policy disagreement. The definition the participants used for avoidance was if the procedure of not participating in a policy or regulation that was not formally adopted. Defiance was defined as the manner of working against a policy or procedure, to bring about change to the policy or procedure. This change in the policy or procedure was usually accomplished by means of working through the regulative body that issued the policy or procedure, but it may involve taking the issue to a court for a ruling.

Implications for Theory

This study contributes to organizational theory, specifically, in task environment and the organizational response. The environmental factors of normative, regulative, and cultural-cognitive dimensions adequately describe the task environment, but this study identifies one factor that influences what the institutions do to adjust themselves to carry on. This factor is geographical setting. Understanding the strengths and weaknesses of a college's geographical setting will allow the program developer to know how to begin an approach to the program development process. These strengths and weakness provide a set of boundaries for the administration when deciding which programs to begin. This study also identified the factor of business and industry partners. Business and industry partners provide the institution with insight into the career path that the college would not necessarily have.

Examining program development as Rojewski (2002) proved to be slightly problematic. The main discrepancy was in the sense of confidence the administrators had when approaching the development of a program. The addition of an environmental factor called geographic setting and the addition of the variable business and industry partnership in the normative dimension gave the study clarity and a more complete explanation of the development of technical education programs.

The strength of this study was the conceptual framework, which pulled together information from reputable theories. As mentioned, the framework demonstrated an effective lens through which to inspect the occupational program development process. It also made the cross-case comparisons on the environmental conditions and organizational response simpler and more understandable.

One closing thought relates to organizational response issues. Some of the variables held by organizational response were ones that participants were uncomfortable in attributing to their organization. For example, most of the participants, when first questioned about the variable avoidance, replied that their institution did not exhibit anything like this response. When pressed and given examples, the participants changed their answers and confirmed that their institutions did exhibit this response and gave examples from their institution. Another aspect of this concern is that most of the participants felt that the responses were part of the process, for example, an institution might exhibit avoidance until it was able to work out another solution that might fall into the variable of manipulation. So to the observer it was the process the institutions followed.

Suggestions for Future Research

This study was designed to be comprehensive in viewing the development of occupational programs in terms of normative, regulative, and cultural-cognitive dimensions and organizational responses. This study should be replicated in other states because Arkansas community colleges are relatively young in the history of higher education. This would verify the transferability of the results of the study of occupational program development to other institutions and states within similar context.

Another good addition to this scholarship would be to include the thoughts and views of state administrators, state two-year college association directors, and regional economic development directors. These individuals will have insights into the need for trained employees for businesses and industries and could help gather a more complete picture of the process of occupational development.

Finally, it would be good to address the development of occupational programs from a perspective of grouping according to matching as many descriptors as possible (i.e., rural community colleges, with student populations approximately the same size, and with similar programs). Holding these factors constant would provide for a more unified look at the colleges. This approach would allow the researcher to fully examine how each specific type of college develops occupational programs and would further aid the practitioners at those institutions.

Dr. Duane E. Doyle is an Assistant Professor of Mathematics at Arkansas State University-Newport

References

Acs, G., & Nichols, A. (2007). *Low-income workers and their employers: Characteristics and challenges.* Washington, DC: The Urban Institute

Andersson, F., Holzer, H., & Lane, J. (2005). *Moving up or moving on: Who advances in the low-wage labor market?* New York: Russell Sage Foundation.

Arkansas Department of Higher Education. (2005, October 22). Revision of criteria and procedures for establishing new certificate and degree programs and organizational units. Retrieved from Arkansas Department of Higher Education: http://www.adhe.edu/SiteCollectionDocuments/AcademicAffairsDivision/Criteria%20and%20Procedures%20for%20Preparing%20Proposals/BookAppNewProgramCriteriaandProceduresRevised2005.pdf

Doyle, D. E. (2011). Developing occupational programs: A case study of four Arkansas community colleges. *Dissertation Abstracts International 73*(02). (UMI No. 3481378)

Friedman, T. L. (2007). *The world is flat: A brief history of the twenty-first century.* New York: Farrar, Straus & Giroux.

Gordon, E. E. (2005). *The 2010 meltdown: Solving the impending jobs crisis.* Westport, CT: Praeger Publishers.

Grubb, W. N. (1999, August 11). *Evaluation of programs.* Retrieved from ED.gov: http://www.ed.gov/rschstat/eval/sectech/nave/grubbi.html

Holzer, H. J., & Lerman, R. I. (2007) *America's forgotten middle-skill jobs.* Retrieved from http://cos.edu/ImageUpload_Links/ForgottenJobsReport.pdf

Lasic, B., & Bunkley, N. (2009, April 27). G.M's latest plan envisions a much smaller automaker. *New York Times.* Retrieved from http://www.nytimes.com

Mishel, L., Bernstein, J., & Allegretto, S. (2005). *The state of working America, 2004/2005.* Ithaca, NY: Cornell University Press.

National Center Education Statistics. (2001). *The condition of education 2001.* Washington DC: Department of Education

Oliver, C. (1991). Strategic responses to institutional processes. *Academy of Management Review* 16 (1), 145-179.

Rojewski, J. W. (2002, February). *Preparing the workforce of tomorrow: A conceptual framework for career and technical education.* Retrieved from National Research Center Career and Technical Education: http://136.165.122.102/UserFiles/File/pubs/PrepWrkfrceAll_Rojewski.pdf

Scott, W. R. (2001). I*nstitutions and organizations.* Thousand Oaks, CA, Sage Publications.

U.S. Bureau of Labor Statistics. (March 12, 2012). *Education pays...* Retrieved from U.S. Bureau of Labor Statistics: http://www.bls.gov/emp/ep_chart_001.htm/

Warren, J. (2000). Collaboration between a small rural community college and a large industrial corporation for customized training. *Community College Journal of Research and Practice, 24*(8), 667– 679.

Table of Contents

Volume XXXVIII, Number 2, Fall 2012

Teacher Perceptions of the Indiana Workplace Specialist I Licensure Training Program during the 2011-2012 Academic Year

Edward J. Lazaros, Samuel Cotton, and Paul B. Brown

Abstract

Alternative teacher licensure, also known as alternative teacher certification, is a growing national trend in education, and it has long been common in the field of career and technical education. Alternatively licensed teachers often enter teaching with a wealth of subject area knowledge due to their previous work experience. Mentorship programs are one of the best ways to help alternatively certified teachers to successfully navigate their first year in the classroom. This study investigated the teacher perceptions of the Indiana Workplace Specialist I (WSI) licensure training program during the 2011-2012 academic year.

Keywords: Alternative, Licensure, Career, Technical, Education

Introduction

Many states offer alternative paths to teacher licensure. According to the National Center for Education Information, "In 2005, 47 states, plus the District of Columbia, report 122 alternative routes to teaching certification being implemented (n.d.). The literature reviewed in this article will present the common strengths and weaknesses of alternatively licensed teachers and explain how mentoring programs can help these new teachers improve and become long-term members of the teaching profession. This article also reports the findings of a 2012 study which described the perceptions of alternatively licensed Indiana teachers (2011/2012) with regard to the Workplace Specialist I (WSI) alternative licensure training project that they participated in during the 2011/2012 academic year. Data will reveal if the teachers' gender, age, computer experience, experience with online education, or occupational area of expertise influenced their perception of the alternative licensure program.

Traditional Certification vs. Alternative Certification

For a traditional education degree (certification-based route), teachers may need to pass standardized tests, meet a minimum grade point average requirement, and earn a degree from a teacher training program at an accredited college or university. Routes to alternative certification vary from state to state, but many are designed to certify teachers who have not completed an undergraduate degree in the field of education. Individuals may become certified more quickly through an alternative route than via a traditional one, which makes alternative certification especially appealing when there is a teacher shortage (Ruhland & Bremer, 2002, pp. 3-4). Alternative teacher certification has helped bring more teachers into the profession, evidenced by the number of alternative certifications issued, which grew nationwide from 4,000 in 1992 to 60,000 in 2006. National Center for Policy Analysis researchers Rebecca Garcia and Jessica Huseman stated that alternative certification programs could have other positive effects, in addition to helping alleviate teacher shortages. "Alternative certification programs attract individuals who are committed to teaching and whose non-teaching experiences are valuable in the classroom" (Garcia & Huseman, 2009, p. 2).

Alternative Licensure in Career and Technical Education

Career and technical education has traditionally been more dependent on alternative teacher licensing based on occupational work experience than other program areas, especially in areas such as trade and industry (Cochran & Reese, 2007; Cotton, 2000; Cotton, Koch, & Harvey, 2010). The roots of CTE teacher certification go back the 1917 Smith-Hughes Act. Teachers in such fields as agriculture, family and consumer science, business, and marketing were expected to have a degree in a related subject area and to have completed professional education coursework. Teachers in industrial education and health fields were usually certified on the basis of their occupational experience and completion of minimal course hours in pedagogy. For example, in 1994, almost half of secondary trade and industrial education teachers did not have a bachelor's degree. However, certified CTE teachers bring with them years of experience working as professionals in their fields of instruction (Ruhland & Bremer, 2002, pp. 7-8, 10).

Teacher Preparation

Ruhland and Bremer (2002) surveyed 178 alternatively licensed CTE teachers and 290 traditionally licensed CTE teachers (with a bachelor's degree in education). The teachers were asked to rate their preparation before they began teaching in the areas of pedagogy, knowledge of subject matter, classroom management skills, and strategies for special populations. Traditionally licensed teachers were twice as likely as alternatively licensed teachers to rate their preparation in the area of pedagogy as "very adequate," and they were 11% more likely to rate their pedagogical preparation as "moderately adequate." In "knowledge of subject matter," 74% of alternatively licensed teachers said they were prepared very adequately, compared to 56% of traditionally licensed teachers. Regarding classroom management skills, alternatively licensed teachers and traditionally licensed teachers were equally likely to rate their preparation as "very adequate" (18% and 20%, respectively). Of alternatively certified teachers, 15% said they were prepared very adequately for working with special populations, compared to 10% of traditionally certified teachers (Ruhland & Bremer, 2002, pp. 31-33). These percentages suggest that traditionally certified teachers felt better prepared in pedagogy, whereas alternatively certified teachers felt more knowledgeable of the subject matter they were teaching. Only a small percentage of teachers in either category felt very adequately prepared in classroom management skills or in special populations strategies.

Teacher Longevity

Ruhland and Bremer (2002) queried CTE teachers about their intentions to continue teaching. More than 50% of all respondents indicated they planned to continue teaching at least eight more years (52% of traditionally licensed teachers and 58% of alternatively licensed teachers). In both of these categories of teachers, 29% said they would probably continue to teach for three to seven more years. Eight percent of traditionally licensed teachers were actively considering leaving the teaching profession, compared to four percent of alternatively licensed teachers (Ruhland & Bremer, 2002, p. 39). Heath-Camp and Camp (1990) found that 15% of CTE teachers left the teaching profession within their first year, and more than half left within six years.

In the Ruhland and Bremer study (2002), alternatively licensed teachers were more likely to stay in the teaching prof ession than were traditionally licensed teachers, indicating that they may have been more satisfied with the profession. However, teachers who come to the profession through alternative licensing feel even less prepared than their traditionally licensed peers for tasks such as creating a positive learning environment and meeting the needs of diverse learners.

Mentorship for Alternatively Licensed CTE Teachers

In the state of Indiana, alternatively certified CTE teachers receive a Workplace Specialist I (WS I) license. They then must complete the WS I training program to be eligible for the Workplace Specialist II license. WS I faculty are assigned mentors during the first year of training to help them adjust to their first year teaching in a classroom. Mentors must have completed five years of kindergarten-12 teaching experience, and they are usually CTE faculty members (Nickolich, Feldhaus, Cotton, Barrett, & Smallwood, 2010, p. 41). Nickolich et al. (2010) surveyed 105 CTE faculty members (60 WS I first-year faculty and 45 mentors) to measure their perceived professional and personal life satisfaction.

"One important finding of this study revealed that Indiana faculty who serve as mentors for first-year CTE faculty were more satisfied with their lives than were the first-year CTE faculty" (Nickolich et al., 2010, p. 47). Many factors may lead to this fact, but one discussed by the researchers is that these older and more experienced faculty members have become "master teachers" through their experiences, thus helping them remain content with their work in spite of increasing pressures and accountability heaped on teachers. The researchers also concluded that experience in teaching leads to more confidence because these mentors had at least five years of teaching experience. Some faculty need time to feel comfortable with teaching. The study concluded with a recommendation to "not underestimate the power of experienced CTE faculty to serve as mentors, coaches, and professional role models for junior faculty" (Nickolich et al., 2010, pp. 47-48).

Well-designed teacher mentoring programs can provide CTE teachers with additional support, thus improving teacher competence, performance, and effectiveness. Mentoring programs for alternatively licensed teachers should be carefully planned and executed so as to minimize confusion on the part of the mentees. Traditionally licensed teachers tend to view mentoring programs as relatively easy to follow, because often they have been learning how to teach since they began their college degrees. However, alternatively licensed teachers come directly from business and industry, so mentoring is a new experience for many of them, and the educational discussions and activities can be confusing (Briggs, 2008, pp. 2, 5-6).

Recommendations for University Coursework and Mentoring Programs

Briggs (2008) surveyed 151 alternatively licensed CTE teachers, all of whom obtained their recommendation for licensure from The Ohio State University between 1995 and 2006. The intent of the study was to measure the teachers' perceptions of how well their university coursework and mentoring activities had prepared them for their teaching careers. The university coursework and clinical experiences that the respondents found most beneficial dealt with practical content, such as student assessment, lesson planning, and classroom management. Respondents perceived a need for distance learning coursework throughout the licensure program in order to reduce travel time to classes. Also, they did not want to waste time repeating material from university coursework in their mentoring activities. According to the respondents, mentoring is most useful when the following factors are met:

- Mentors and mentees are carefully matched based on similar teaching content,
- Duplication of university materials and employment materials is reduced,
- Paperwork is reduced as much as possible,
- Employers realize that alternatively licensed CTE mentees are overwhelmed,
- And mentors actually take the time to meet with their mentees. (Briggs, 2008, pp. 84-85)

The need for mentorship for alternatively licensed CTE teachers is clear. Alternative certification has grown in popularity recently, in large part the result of teacher shortages, but alternative ways for teachers to enter the classroom have long been common in the field of CTE. Alternatively certified CTE teachers bring an increased knowledge of the subject matter to the classroom as a result of their business and industry experiences prior to teaching. However, they must be given extra preparation in the area of pedagogy to fully prepare them to be teachers. Teachers become more confident and more effective as they gain experience in the classroom, which is why they need extra help during the first year of teaching. Effective mentoring programs can make a significant difference for alternatively certified teachers, who may be often overwhelmed by their transition to the classroom. By guiding and assisting alternatively certified teachers in key areas, mentors can help the teachers overcome common challenges during their first year, while allowing the teachers' strengths to shine through.

Problem Statement

There is a lack of information related to the perceptions of Indiana WSI teachers with regard to the 2011/2012 WSI teacher training project that they completed.

Purpose of the Study

The purpose of this study was to ascertain the perceptions of Indiana 2011/2012 WSI teachers with regard to the WSI teacher training project that they participated in during the 2011/2012 academic year. These perceptions will provide the individuals involved with the project with data that could guide future program improvement.

The following research questions guided this study:

1. What are the perceptions of teachers with regard to the WSI teacher training project?
2. Did the teachers' gender influence their perception of the WSI teacher training project?
3. Did the teachers' age influence their perception of the WSI teacher training project?
4. Did the teachers' computer experience influence their perception of the WSI teacher training project?
5. Did the teachers' experience with online education influence their perception of the WSI teacher training project?
6. Did the teachers' occupational area of expertise influence their perception of the WSI teacher training project?

Description of the Subject Population

In the state of Indiana, the Indiana Department of Education offers an alternative license known as the Workplace Specialist I (WSI). This license allows an individual to teach in an occupational area in a career center.

A university degree is not required for this type of teaching license, but the individual must have at least a high school diploma or a GED. Also, 6,000 hours of documented work experience in the occupational area for which the individual is to be licensed to teach are required. The hours of documented work experience can be reduced if the individual completes a 2-year degree in the occupational area of the requested license (e.g., automotive technology). The 6,000-hour requirement also can be reduced if an individual completed two years (1,020 hours) in a high school career and technical education (CTE) program in the specific occupational area, holds a license or certification in the occupational area, or completed a formal internship or apprenticeship in the occupational area.

To pursue this alternative path toward licensure, an individual must first be hired and contracted by a school to teach an identified occupational area. Once under contract with a school, the individual applies for the WSI license with the Indiana Department of Education. The individual then applies for the WSI teacher training program during his/her first year of teaching. This WSI teacher training program has a hybrid delivery system. The teachers attend two live remote site training sessions lead by project instructors with assigned locations determined by geography. The teachers participate in online coursework delivered by project instructors in one of eight groups assigned by licensed program area. Mentors with a minimum of five years of teaching experience in a closely related content area assist, supervise, and observe the WSI licensee during the year-long training program. The mentors conduct formal teaching observations that are shared with the project instructors and coordinator. A collaborative environment exists in online discussion forums between teachers and the project instructors. The content of the training program includes classroom management, writing and using standards-based learning objectives, conducting classroom and curriculum assessments, integrating academics into occupational program areas, lesson planning, accessing instructional materials, understanding advisory committees, understanding career and technical student organizations, and understanding how to develop professional development plans. All teachers who participated in the Indiana 2011/2012 WSI teacher training project were invited to participate in this study.

Methodology

Descriptive research was used to investigate data from Indiana WSI teachers who completed the 2011/2012 WSI teacher training project. The population for this study consisted of Indiana WSI teachers ($N = 64$) who completed the 2011/2012 WSI teacher training project. The university students were grouped by their gender (Male / Female), age (22-34, 35-44, 45-54, 55-64, 65 and over), computer experience (No Experience, Some Experience, Experienced, Very Experienced), experience with online education (No Experience, Some Experience, Experienced, Very Experienced), and occupational area of expertise (computer/graphics/PLTW, culinary arts, health sciences, machine/welding/industrial technology, medley), and level of education (GED, high school diploma, some postsecondary training, associate's degree, bachelor's degree, master's degree, doctorate degree). The response rate of the WSI teachers was 72% ($N = 46$).

The survey instrument was used to gather demographic information in the following categories: (1.) Gender, (2.) Age, (3.) Computer Experience, (4.) Experience with Online Education, (5.) Occupational Area of Expertise, and (6.) Level of Education.

The perceptions of Indiana WSI teachers who completed the 2011/2012 WSI teacher training project were investigated using the following nine questions:

1. The WSI teacher training project helped me with classroom management.
2. The WSI teacher training project helped me write and use standards-based learning objectives.
3. The WSI teacher training project helped me with classroom and curriculum assessment.
4. The WSI teacher training project helped me integrate academics into my occupational program area.
5. The WSI teacher training project helped me with lesson planning.
6. The WSI teacher training project helped me learn how to access instructional materials.
7. The WSI teacher training project helped me understand advisory committees.
8. The WSI teacher training project helped

me understand career and technical student organizations.

9. The WSI teacher training project helped me understand how to develop a professional development plan.

Results

Demographic Results

Regarding gender, survey respondents were evenly split between males (*n* = 23) and females (*n* = 23). In terms of age, survey respondents were mostly between 35-44 (*n* = 27, 58.7%). See Table 1 for more information.

Table 1. Age

	Frequency	Percent	Valid Percent	Cumulative Percent
22-34	**3**	**6.5**	**6.5**	**6.5**
35-44	**27**	**58.7**	**58.7**	**65.2**
45-54	**6**	**13.0**	**13.0**	**78.3**
55-64	**9**	**19.6**	**19.6**	**97.8**
65 and over	**1**	**2.2**	**2.2**	**100.0**
Total	**46**	**100.0**	**100.0**	

Regarding computer experience, almost half reported some computer experience (*n* = 22, 47.8%). See Table 2 for more information.

Table 2. Computer Experience

	Frequency	Percent	Valid Percent	Cumulative Percent
No Experience	1	2.2	2.2	2.2
Some Experience	22	47.8	47.8	50.0
Experienced	14	30.4	30.4	80.4
Very Experienced	9	19.6	19.6	100.0
Total	46	100.0	100.0	

For experience with online education, many respondents had no experience (*n* = 19, 41.3%) or only some experience (*n* = 17, 37.0%). See Table 3 for more information.

Table 3. Experience with Online Education

	Frequency	Percent	Valid Percent	Cumulative Percent
No Experience	19	41.3	41.3	41.3
Some Experience	17	37.0	37.0	78.3
Experienced	7	15.2	15.2	93.5
Very Experienced	3	6.5	6.5	100.0
Total	46	100.0	100.0	

For primary occupational area of expertise, the most frequent type of occupation was health sciences (*n* = 20, 43.5%). See Table 4 for more information.

Table 4. Primary Occupational Area of Expertise

	Frequency	Percent	Valid Percent	Cumulative Percent
Computer/ Graphics/PLTW	3	6.5	6.5	6.5
Culinary Arts	5	10.9	10.9	17.4
Health Sciences	20	43.5	43.5	60.9
Machine/Welding/ Industrial Technology	9	19.6	19.6	80.4
Multiple or Other	9	19.6	19.6	100.0
Total	46	100.0	100.0	

For highest level of education, associate's degree (n = 17, 37.0%) and bachelor's degree (*n* = 14, 30.4%) were most common. See Table 5 for more information.

Research question one sought to investigate the perceptions of teachers who participated in the WSI teacher training project. Responses were collected from the WSI teacher to determine if the training project was helpful. Teachers strongly agreed and agreed the WSI teacher training project was

Table 5. Highest Level of Education

	Frequency	Percent	Valid Percent	Cumulative Percent
high School Diploma	2	4.3	4.3	4.3
Some Postsecondary Training	10	21.7	21.7	26.1
Associate's Degree	17	37.0	37.0	63.0
Bachelor's Degree	14	30.4	30.4	93.5
Master's Degree	2	4.3	4.3	97.8
Doctorate Degree	1	2.2	2.2	100.0
Total	46	100.0	100.0	

helpful with classroom management 71.1% (n = 45), using standards-based objectives 80.0% (n = 45), classroom and curriculum assessment 75.5% (n = 45), integrating academics into occupational program areas 73.4% (n = 45), lesson planning 71.1% (n = 45), learning how to access instructional materials 66.7% (n = 45), understanding advisory committees 73.4% (n = 45), understanding career and technical student organizations 73.3% (n = 45), and understanding how to develop a professional development plan 77.8% (n = 45). See Table 6 for more information.

Table 6. Perceptions of Teachers with Regard to the WSI Teacher Training Project

The WSI Teacher Training Project Helped Me	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	n
With Classroom Management	24.4%	46.7%	17.8%	6.7%	4.4%	45
Write and Use Standards-Based Learning Objectives	31.1%	48.9%	17.8%	0.0%	2.2%	45
With Classroom and Curriculum Assessment	24.4%	51.1%	6.7%	13.3%	4.4%	45
Integrate Academics Into My Occupational Program Area	26.7%	46.7%	13.3%	6.7%	6.7%	45
With Lesson Planning	31.1%	40.0%	11.1%	8.9%	8.9%	45
Learn How to Access Instructional Materials	20.0%	46.7%	17.8%	8.9%	6.7%	45
Understand Advisory Committees	26.7%	46.7%	17.8%	4.4%	4.4%	45
Understand Career and Technical Student Organizations	24.4%	48.9%	17.8%	6.7%	2.2%	45
Understand How to Develop A Professional Development Plan	26.7%	51.1%	8.9%	4.4%	8.9%	45

Research question two sought to investigate if the teachers' gender influenced their perception of the WSI teacher training project. Males more than females agreed that WSI teacher training helped with classroom management (t = -3.768, df = 29.92, p = .001), using standards-based learning objectives (t = .2.430, df = 42, p = .019), integrating academics into their occupational area (t = 3.038, df = 29.48, p = .005), learning how to access instructional materials (t = -2.600, df = 36.46, p = .013), understanding advisory committees (t = -2.478, df = 30.22, p = .019), and learning how to develop a professional development plan (t = -2.149, df = 30.93, p = .040). No other differences in agreement were found for the survey items in this section. See Table 7 for means and standard deviations.

Research question three sought to investigate if the teachers' age influenced their perception of the WSI teacher training project. Two age groups were created, which were less than 44 years of age (22-44) and greater than 45 years of age (45 and over). Those that were ages 22-44 did not find WSI teacher training as helpful as those who were 45 and older (t = 2.390, df = 42.96, p = .021). No other differences in agreement were found for the survey items in this section. See Table 8 for means and standard deviations.

Research question four sought to investigate if the teachers' computer experience influenced their perception of the WSI teacher training project. Two groups were created: some experience

Table 7. The Influence of Gender on the Perception of the WSI Teacher Training Project

Group Statistics	Gender	N	Mean	SD	t	df	p
With Classroom Management	Male	23	1.70	.559	-3.768	29.92	.001
	Female	22	2.73	1.162			
Write and Use Standards-based Learning Objectives	Male	23	1.65	.573	-2.430	43	.019
	Female	22	2.23	.973			
With Classroom and Curriculum Assessment	Male	23	2.09	.949	-.836	43	.408
	Female	22	2.36	1.255			
Integrate Academics Into My Occupational Program Area	Male	23	1.74	.619	-3.038	29.48	.005
	Female	22	2.68	1.323			
With Lesson Planning	Male	23	1.96	1.186	-1.614	43	.114
	Female	22	2.55	1.262			
Learn How to Access Instructional Materials	Male	23	1.96	.825	-2.600	36.46	.013
	Female	22	2.77	1.232			
Understand Advisory Committees	Male	23	1.78	.600	-2.478	30.22	.019
	Female	22	2.50	1.225			
Understand Career and Technical Student Organizations	Male	23	1.91	.668	-1.613	33.69	.116
	Female	22	2.36	1.136			
Understand How to Develop A Professional Development Plan	Male	23	1.83	.717	-2.149	30.93	.040
	Female	22	2.55	1.405			

Table 8. Influence of Teachers' Age on Their Perception of the WSI Teacher Training Project

Group Statistics	**Age**	***N***	**Mean**	***SD***	***t***	***df***	***p***
With Classroom Management	22-44	29	2.14	.953	-.537	43	.594
	45 and over	16	2.31	1.195			
Write and Use Standards-based Learning Objectives	22-44	29	1.97	.823	.344	43	.733
	45 and over	16	1.88	.885			
With Classroom and Curriculum Assessment	22-44	29	2.38	1.178	1.293	43	.203
	45 and over	16	1.94	.929			
Integrate Academics Into My Occupational Program Area	22-44	29	2.21	1.114	.055	43	.956
	45 and over	16	2.19	1.167			
With Lesson Planning	22-44	29	2.52	1.379	2.390	42.96	.021
	45 and over	16	1.75	.775			
Learn How To Access Instructional Materials	22-44	29	2.45	1.213	.750	43	.457
	45 and over	16	2.19	.911			
Understand Advisory Committees	22-44	29	2.14	1.026	.041	43	.968
	45 and over	16	2.13	1.025			
Understand Career And Technical Student Organizations	22-44	29	2.10	.900	-.283	43	.779
	45 and over	16	2.19	1.047			
Understand How To Develop A Professional Development Plan	22-44	29	2.14	1.125	-.309	43	.759
	45 and over	16	2.25	1.238			

and experienced. The experienced group was composed of responses from the experienced and very experienced groups. No differences in agreement levels were found based on self-reported computer experience by the WSI survey participants. See Table 9 for more information.

Research question five sought to investigate if the teachers' experience with online education influenced their perception of the WSI teacher training project. Three groups were created: no experience, some experience, and experienced. The experienced group was composed of responses from the experienced and very experienced groups. There were differences in agreement levels for how helpful the WSI teacher training project was in assisting with classroom and curriculum assessment based on prior online education experience ($F_{(2,19.67)}$ = 3.632, p = .045). Using the Games-Howell Post-Hoc test no pairwise differences were found; however, there did appear to be more agreement for those with some experience than those with

Table 9. Influence of Teachers' Computer Experience on the Perception of the WSI Teacher Training Project

Group Statistics	Computer Experience	N	Mean	SD	t	df	p
With Classroom Management	Some Experience	22	2.05	.999	-1.175	42	.247
	Experienced	22	2.41	1.054			
Write and Use Standards-based Learning Objectives	Some Experience	22	1.82	.664	-1.087	42	.283
	Experienced	22	2.09	.971			
With Classroom and Curriculum Assessment	Some Experience	22	2.14	.941	-.535	42	.595
	Experienced	22	2.32	1.287			
Integrate Academics Into My Occupational Program Area	Some Experience	22	2.00	.873	-1.204	36.21	.236
	Experienced	22	2.41	1.333			
With Lesson Planning	Some Experience	22	2.00	.926	-1.472	35.38	.150
	Experienced	22	2.55	1.471			
Learn How to Access Instructional Materials	Some Experience	22	2.05	.844	-1.795	36.15	.081
	Experienced	22	2.64	1.293			
Understand Advisory Committees	Some Experience	22	2.09	.868	-.291	42	.772
	Experienced	22	2.18	1.181			
Understand Career and Technical Student Organizations	Some Experience	22	2.18	.907	.474	42	.638
	Experienced	22	2.05	.999			
Understand How to Develop A Professional Development Plan	Some Experience	22	1.95	.899	-1.302	36.27	.201
	Experienced	22	2.41	1.368			

no experience or more extensive experience. There were differences in agreement levels for how helpful the WSI teacher training project was in assisting with lesson planning based on prior online education experience ($F_{(2,20.02)}$ = 4.429, p = .026). Using the Games-Howell Post-Hoc test, those with some online education experience reported the training more useful than those who had more extensive online education experience (p = .029). See Table 10 for more information.

Research question six sought to investigate if the teachers' occupational area influenced their perception of the WSI teacher training project. Of the 46 respondents, 20 were in health sciences and the other categories had very few respondents. Statistical testing was not pursued due to the low number of responses in the categories.

Discussion

Before this study was conducted, little was known about the perceptions of teachers who participated in the WSI teacher training project during the 2011-2012 academic year. This study yielded information that indicated the training project was helpful to the teachers. Teachers strongly agreed (or agreed) that the WSI teacher training project was helpful with classroom management 71.1% (n = 45), writing and using standards-based objectives 80.0% (n = 45), classroom and curriculum assessment 75.5% (n = 45), integrating academics into occupational program areas 73.4% (n = 45), lesson planning 71.1% (n = 45), learning how to access instructional materials 66.7% (n = 45), understanding advisory committees 73.4% (n = 45), understanding career and technical student organizations 73.3% (n = 45), and understanding how to develop a professional development plan 77.8% (n = 45). The results of this study indicated that males more than females agreed that WSI teacher training helped with classroom management (t = -3.768, df = 29.92, p = .001), with writing and using standards-based learning objectives (t = .2.430, df = 42, p = .019), with integrating academics into their occupational area (t = 3.038, df = 29.48, p = .005), with how to access instructional materials (t = -2.600, df = 36.46, p = .013), with understanding advisory committees (t = -2.478, df = 30.22, p = .019), and with understanding how to develop a professional development plan (t = -2.149, df = 30.93, p = .040). Teachers who were 22-44 did not find the WSI teacher training as helpful as those who were 45 years of age and over (t = 2.390, df = 42.96, p = .021). Teachers with some online education experience reported the training more useful than those who had more extensive online education experience (p = .029).

Conclusion

Prior to this study, there was a lack of information about the perceptions of Indiana WSI teachers with regard to the 2011/2012 WSI

Table 10. Influence of Teachers' Experience with Online Education on the Perception of the WSI Teacher Training Project

Group Statistics

		N	Mean	SD	F	df1	df2	p
With Classroom Management	No Experience	19	2.11	1.049	.965	2	42	.389
	Some Experience	16	2.06	.998				
	Experienced	10	2.60	1.075				
	Total	45	2.20	1.036				
Write and Use Standards-Based Learning Objectives	No Experience	19	1.84	.765	1.254	2	42	.296
	Some Experience	16	1.81	.655				
	Experienced	10	2.30	1.160				
	Total	45	1.93	.837				
With Classroom and Curriculum Assessment	No Experience	19	2.26	1.046	3.632	2	19.67	.045
	Some Experience	16	1.75	.577				
	Experienced	10	2.90	1.524				
	Total	45	2.22	1.106				
Integrate Academics Into My Occupational Program Area	No Experience	19	2.16	.958	1.521	2	20.82	.242
	Some Experience	16	1.88	.885				
	Experienced	10	2.80	1.549				
	Total	45	2.20	1.120				
With Lesson Planning	No Experience	19	2.00	1.106	4.429	2	20.02	.026
	Some Experience	16	1.81	.655				
	Experienced	10	3.40	1.578				
	Total	45	2.24	1.246				
Learn How to Access Instructional Materials	No Experience	19	2.32	.885	2.571	2	20.62	.101
	Some Experience	16	1.94	.854				
	Experienced	10	3.10	1.524				
	Total	45	2.36	1.111				
Understand Advisory Committees	No Experience	19	2.05	.780	.445	2	20.16	.647
	Some Experience	16	2.00	.894				
	Experienced	10	2.50	1.509				
	Total	45	2.13	1.014				
Understand Career and Technical Student Organizations	No Experience	19	2.11	.809	1.113	2	42	.338
	Some Experience	16	1.94	.854				
	Experienced	10	2.50	1.269				
	Total	45	2.13	.944				
Understand How to Develop A Professional Development Plan	No Experience	19	2.26	1.195	.723	2	19.96	.498
	Some Experience	16	1.94	.680				
	Experienced	10	2.40	1.647				
	Total	45	2.18	1.154				

teacher training project that they completed. This article yielded some new information to the knowledge base pertaining to alternative route teachers. It reported the findings of a 2012 study that showed the perceptions of alternatively licensed Indiana teachers with regard to the WSI alternative licensure training project that they participated in during the 2011/2012 academic year. Data revealed that the alternatively licensed teachers either agreed or strongly agreed that the WSI teacher training project was helpful with classroom management, using standards-based objectives, classroom and curriculum assessment, integrating academics into occupational program areas, lesson planning, learning how to access instructional materials, understanding advisory committees, understanding career and technical student organizations, and understanding how to develop a professional development plan. As reported, some groups compared to others felt that the WSI alternative licensure training project was more helpful; however, alternative licensure appears to be helpful overall to the teachers surveyed in this small Indiana study.

Recommendations for Further Research

Future research should be conducted to ascertain the perceptions of Indiana WSI teachers with regard to future WSI teacher training projects. These perceptions could guide continued program improvement. Future studies should incorporate open-ended responses or focus groups to investigate why males more than females agree that the WSI teacher training program assisted with classroom management, writing and using standards-based learning objectives, integrating academics into an occupational area, accessing instructional materials, understanding advisory committees, and understanding how to design a professional development plan. Open-ended responses also may yield insight into why teachers who were 22-44 did not find the WSI teacher training as helpful as those who were 45 years or age and over. Furthermore, these types of responses may help to gain insight into why teachers with some online education experience reported the training more useful than those who had more extensive online education experience. Replication of this study in other states is recommended to determine if there are similar issues and results in larger regions or nationally.

Dr. Edward J. Lazaros is an assistant professor in the Department of Technology at Ball State University Muncie, Indiana, and coordinator of the Master of Arts Degree in Career and Technical Education.

Dr. Samuel Cotton is an associate professor and Chairperson in the Department of Technology at Ball State University, Muncie, Indiana.

Paul B. Brown is a graduate of Ball State University, Muncie, Indiana.

References

Briggs, J. E. (2008). *Perceptions of alternatively-licensed career and technical education teachers about teacher mentoring and teacher retention.* (Unpublished doctoral dissertation). The Ohio State University.

Cochran. L., & Reese, S. (2007). A successful introduction into the teaching profession. *Techniques: Connection Education and Careers, 83*(1), 25-27.

Cotton, S. E., Koch, K. R., & Harvey, M. W. (2010). Adapting school environments to special needs. *Academic Exchange Quarterly, 14*(1), 164-169.

Cotton, S. E. (2000). Professional development needs assessment for secondary vocational and technical education teachers related to students with special needs. *Academic Exchange Quarterly, 4*(2), 33-40.

Garcia, R., & Huseman, J. (2009). Alternative certification programs: Meeting the demand for effective teachers. *National Center for Policy Analysis, Brief analysis No. 675.*

Heath-Camp, B., & Camp, W. G. (1990). What new teachers need to succeed. *Vocational Education Journal, 65*(4), 22-24.

National Center for Education Information (n.d.). Alternative routes to teacher certification: and overview. Retrieved from http://www.ncei.com/Alt-Teacher-Cert.htm.

Nickolich, D., Feldhaus, C., Cotton, S., Barrett, A., II, & Smallwood, J. (2010). Perceived life satisfaction of Workplace Specialist I faculty and mentors participating in a first-year STEM teacher training project. *Journal of Technology Studies, 36*(2), 41-54.

Ruhland, S. K., & Bremer, C. D. (2002). *Alternative teacher certification procedures and professional development opportunities for career and technical education teachers.* St. Paul, MN: National Dissemination Center for Career and Technical Education.

Gender Difference of Confidence in Using Technology for Learning

Hon Keung Yau and Alison Lai Fong Cheng

Abstract

Past studies have found male students to have more confidence in using technology for learning than do female students. Males tend to have more positive attitudes about the use of technology for learning than do females. According to the Women's Foundation (2006), few studies examined gender relevant research in Hong Kong. It also appears that no studies have examined these gender differences in the perception of confidence in using technology for learning specifically in Hong Kong. The aim of this study was to examine gender difference regarding confidence toward using technology (e.g., AutoCAD, SPSS, Compiere, Arena, and programming language, such as C, Java, Visual Basic, etc.) for learning in higher educational institutions in Hong Kong. The study employed a survey methodology collecting 211 questionnaires from one specific university in Hong Kong. The findings confirmed that male students have more confidence in using technology for learning than do female students because gender imbalances in computing are socially constructed and not related to a learner's innate ability. It is recommended that the universities should set up training courses for female students so these students can build confidence in using technology for learning.

Key words: Confidence; Gender difference; Hong Kong higher education; technology and learning

Introduction

Motivation is an essential factor in learning, and it affects all fields of education (Kahveci, 2010). Appropriate teaching methods that motivate students result in effective learning. Hong Kong has experienced a wider range of educational opportunities for females during the past two decades (The Women's Foundation, 2006). Since 1996, Hong Kong has also experienced a trend where more female students than male students have entered Hong Kong universities (University Grant Council Hong Kong, 2010). Most educational research in Hong Kong has not been gender specific (The Women's Foundation, 2006). One study found in the literature (Kahveci, 2010), only focused on the students' perceptions of the use of technology. However, it appears that few research studies have focused on undergraduates' gender difference in the use of educational technology, particularly higher education in Hong Kong. Thus, the purpose of this study was to determine if there are student differences of confidence between males and females in using technology for learning in Hong Kong higher educational institutions. This study used a survey methodology at one Hong Kong university to answer the following question: "Do male students have more confidence in using technology for learning than do female students?"

Literature Review

In Hong Kong, as in other parts of the modern world, students use technology for learning, including word processing, Internet surfing, educational software applications, and programming. Students gain experience with word processing, information from the Internet, and educational software during their primary and secondary school education. In Hong Kong, as in other locations, university students are required to use technology for learning in applications (using Blackboard to download teaching materials, Microsoft Office to complete reports and projects, and email to contact professors and instructors). In addition, there are many technology-related courses in university departments. Students have more opportunities to access educational technology, such as AutoCAD, SPSS, Compiere, and Arena and to take related computer courses to learn programming, such as C, Java, Visual Basic and more. Those technologies were investigated in this study.

Confidence in using technology for learning

According to education research, students are not motivated to learn if they do not have sufficient confidence in using technology for learning (Keller, 2010). Additionally, technology may cause students to fear the topic, skill, or situation because they have had negative or inadequate experience in using technology for learning previously. In contrast, learners might believe incorrectly that they already know the target information or learning task and then overlook the important details in the learning activities (Keller, 2010). To avoid this situation, three strategies should be followed: learning requirements, success opportunities, and personal control. Learning requirements can be used as a strategy to build a positive expectation for success. Success opportunity is a method to enhance the students' beliefs in their individual and personal competence. Personal control is a tactic to let the learners know their success has been more clearly based on their efforts and abilities (Keller, 2010).

Gender difference in using technology for learning

Much literature exists that has found that men and women have been characterized by a range of social and biological differences. The role of gender differences in using technology for learning has been extensively researched (Kahveci, 2010). In past studies authors found that using technology for learning is a dominant activity for males and that males have positive attitudes toward using technology for learning more than do females (Kadijevich, 2000; Li & Kirkup, 2007). Moreover, when equal access is provided to all students, females are less likely to use computers than males because females perceive that using technology for learning is predominately a male activity (Hwang, Suk, Fisher, & Vrongistinos, 2009; Kirkup, 1995). Gender stereotypes affect students easily because of societal influences. For example, although females excelled in male-dominant subjects like technology, they were still dismissive about their achievement and feigned clumsiness to retain a feminine image (Hwang et al., 2009; Joiner et al., 2011). Similarly, Comber and Colley (1997) reported that girls perceived themselves being the same as boys to be a part of a computer culture, but males still dominate stubbornly in computing. In addition, Dhindsa and Shahrizal-Emran (2011) found that female students had a strong belief in the equality of both sexes in using technology activities. Thus, the above findings show that there is gender difference in using technology for learning.

Females are less likely to be attracted to computer courses than are males, because computer courses are a traditionally dominant activity for males, and thus females lose interest in using technology for learning (Li & Kirkup, 2007). Even though females may be interested in using technology for learning, most female students have less confidence when compared to males (Comber & Colley, 1997). Another study found more females than males indicated that computers are useful, but females found it less enjoyable to learn to use computers than did males (Kaino, 2008). A number of other studies found that females are less confident in using technology and more anxious to use it for learning (Dhindsa & Shahrizal-Emran, 2011; Kirkpatrick & Cuban, 1998). Additionally, women had more difficulty in searching the Internet than did men (GVU Center at Georgia Tech, 1998). Interestingly, Li and Kirkup (2007) compared Chinese and Western students on gender differences in the use of technology for learning; they reported that both Chinese and British male students had more confidence than did female students about their computer skills, and they agreed that using a computer is a male-dominant activity. Thus, this case applies both to Western and Asian cultures.

Based on the above evidence, this study made the following hypotheses:

H0: There is no difference among male and female students' confidence in using technology for learning in Hong Kong higher education.

H1: Male students in this study will have greater confidence in using technology for learning than will female students in Hong Kong higher education.

Methodology

This study employed a survey technique using a questionnaire administered to students in a convenience sample.

Questionnaire

In this study, a questionnaire survey was conducted to collect student data needed to determine if there are indeed confidence gender differences in using technology for learning (where technology was defined as the use of computer applications, such as AutoCAD, SPSS, Compiere, and Arena and exposure to programming languages, such as C, Java, Visual Basic, etc.). For the purpose of this study the confidence variable was measured by using a modified Fennema-Sherman Attitude Scale (Kahveci, 2010) specifically modified for a questionnaire used to investigate if there were gender difference of student confidence in using technology for learning. This variable consisted of five questions (Table 1) that were rated according to a 5-point Likert-type scale, ranging from 1 "strongly agree" to 5 "strongly disagree."

Table 1. Items of the Study Questionnaire

Question	Items	Factor loading
1.	I am sure I can do advanced work in technology.	0.712
2.	I am sure I can use technology.	0.516
3.	I think I could handle more difficult technology problems.	0.711
4.	I can get good grades in the courses related to technology.	0.726
5.	I have a lot of confidence when it comes to the use of technology.	0.774

Pilot study

To assure having a useable instrument, the authors conducted a pilot study to determine if the chosen questions worked as intended and were effective for collecting useful information based on best practices (Lowe, 2006). In the pilot study, a convenience sample of 12 students completed questionnaires to determine if items needed wording or other changes to reduce potential nonresponse rates as suggested by Oppenheim (1992). Subjects were asked to complete the questionnaire without any explanation to determine whether they understood the questions in the instrument. In addition, each subject supplied individual feedback. We found some questions too similar and some too difficult for the subjects to understand. A revised questionnaire removed duplicate items and rephrased others, making the questions easier to understand. The revised instrument was further pilot tested by 10 additional subjects. With the additional pilot study, we found students understood the questionnaire content, and they did not object to its length.

Parent study

After the pilot study, questionnaires were distributed to a larger number of students studying business, engineering, social science, and other disciplines at the selected university. The sample for this study included year 1 through year 3 students attending a local Hong Kong university that included students who were experienced with the educational technology in their university courses or in high school. Therefore, we determined that this sample was valid for collecting information about student motivation in using technology for learning. In total, 211 of the 350 questionnaires distributed were returned, resulting in a 60.29% response rate. All returned questionnaires were useful because the data was relevant and the questionnaires were fully completed.

Validity and reliability analysis

Prior to conducting bivariate and t-test analysis, the data set was examined to ensure it was amenable for these techniques. We examined responses to each question minimize invalid responses and missing values. Then we employed Cronbach's alpha to test the reliability of the variable. The Cronbach's alpha value of confidence was 0.886. Normally, the alpha value should be greater than 0.7 for well-established measures (Peterson, 1994; Valeberg et al., 2009). We consider the results to be consistent and reliable because the alpha value in this survey was greater than 0.7.

Factor loading is the means of interpreting the role each variable plays in defining each factor. Factor loadings are the correlation of each variable and the factor. Loadings indicate the degree of correspondence between the variable and the factor, with higher loadings making the variable representative of the factor (Valeberg et al., 2009). Table 1 also shows that five items of confidence ranged from 0.516 to 0.726. They were all retained because only factor loadings on the attributes greater than 0.3 were suitable for interpretation (Valeberg et al., 2009).

Results

Demographic data

As stated previously, 211 questionnaires were returned. Table 1 shows the demographic data of respondents. Of these, male students completed 51.7% and female students completed 48.3%; 35.1% of respondents were under age 21, and 58.3% of respondents ranged between 21 and 25 years of age, 4.7% of respondents ranged between 26 and 30 years of age, and 1.9% of respondents ranged between 31 and 35 years of age. Over 28% of respondents were year 1 students, 35.5% were year 2 students, and 36% were year 3 students. In addition, 85.8% were full-time students, 13.3% were part-time students, and 0.9% were exchange students.

Mean, standard deviation and t-test

The means and standard deviation were calculated to analyze the data. Table 2 shows that the mean value for female students was 3.0569, which was higher than that of male students

Table 2. Statistics of the Personal Data of Respondents

Personal Details	No. of respondents	Percentage of respondents (%)
Gender		
Male	109	51.7
Female	102	48.3
Age		
< 21	74	35.1
21-25	123	58.3
26-30	10	4.7
31-35	4	1.9
Year of Study		
Year 1	60	28.4
Year 2	75	35.5
Year 3	76	36.0
Mode of study		
Full time	181	85.8
Part time	28	13.3
Exchange	2	0.9

(mean = 2.6495). The findings show that male students have more confidence in using technology for learning than do female students. The *t*-test was then used to test the significant difference between the two genders' confidence in using technology for learning. The findings showed that there is significant difference between the perception of males and females ($t = -3.563$, $p < 0.001$) and that males have more confidence in using technology for learning. This finding was also supported by Kahveci (2010), Kirkpatrick and Cuban (1998), Li and Kirkup (2007), Shashaani and Khalili (2001), and Kaino (2008). Therefore, the hypothesis H0 was rejected in support of H1.

The finding in this research showed that both male and female students in the study university liked to learn to use technology. This particular university provides learners proper and sufficient educational technology on campus, including computers, laptops, and software.

Table 3: Summary Table of Gender Statistics in Gender Difference in Confidence

Gender	*N*	Mean	Std. Deviation
Male	109	2.6495	.83095
Female	102	3.0569	.82887

Discussion

Based on the finding of this study, male students were more confident in using technology for learning than were female students in higher education in Hong Kong. Similar findings were reported by other researchers. For example, research conducted by Shashaani and Khalili (2001) revealed that even female students agreed there is gender inequality in the use of technology, and they had little confidence in using technology for learning as compared to male students. Literature suggests the reasons for such gender imbalances in computing are socially constructed and are not related to innate ability (Joiner et al., 2011). Teachers, parents, and peer groups influence student attitudes toward computing (Shashaani & Khalili, 2001). For example, some parents may believe using technology to be a male activity and consequently they may give biased feedback to their children on career choices or may misrepresent the importance that this subject should have in high school; such attitudes would make little progress in removing the observed gender bias in student confidence in learning with technology.

In addition, students use such technology daily, thus building their confidence in the use of technology for learning. For example, teachers upload course materials to blackboard and students download materials through blackboard. Most students would check their email every day. Practically all students use applications such as Microsoft Office to accomplish projects and assignments. Most students search for information on the Internet when completing term papers and projects. Extensive research has found that the use of the Internet motivates student learning and provides students with effective learning environments (Langin, Ackerman, & Lewark, 2004; O'Bannon & Puckett, 2010), online courses (Kim, Liu, &

Bonk, 2005), blackboards (Lang, 2008), discussion boards (Clyde & Delohery, 2004; Lang, 2008), email (Clyde & Delohery, 2004), library databases (Clyde & Delohery, 2004), Microsoft Word, Excel, PowerPoint (Lawrence, 2003), and laptops (Changchit, Cutshall, & Elwood, 2008). Therefore, both male and female students can be positioned to have a positive attitude toward the use of technology for learning and to become more motivated to use technology for learning under the e-learning environment.

Conclusion

The findings in this study show that male students have more confidence in using technology for learning than do female students in higher education in Hong Kong. This study can contribute to reducing gender difference regarding student confidence toward using technology for learning in Hong Kong higher education by ensuring that all students have access to and are encouraged to use technology in learning. Based on this study's findings, we can understand more about both male and female students' perception of confidence in using technology (e.g., AutoCAD, SPSS, Compiere, and Arena and some programming language, such as C, Java, Viusal Basic, etc.) for learning. These findings should also encourage university educators in Hong Kong to integrate technological components into their courses to enhance student confidence in using technology for learning. In addition, it is recommended that the universities should set up training courses for female students. The female students can build their confidence in using technology for learning through such training courses.

Suggestions for Additional Research

Because this study was limited to a small sample at a single Hong Kong university using a single survey instrument for data collection, additional studies should be conducted employing mixed methods of data collection. Additional qualitative techniques, such as interviews and focus groups, could be used to explore other reasons why female students have less confidence in using technology for learning than do male students in Hong Kong higher education. In order to improve the generalization, we should focus on all of Hong Kong's universities. Further ideas for reversing this difference should be explored for future generations of Hong Kong students so that they can be freed of the observed bias.

Dr. Hon Keung Yau is in the Department of Systems Engineering and Engineering Management at the City University of Hong Kong.

Dr. Alison Lai Fong Cheng is an independent researcher in Hong Kong.

References

Arch, E. C., & Cummins, D. E. (1989). Structured and unstructured exposure to computers: Sex differences in attitude and use among college students. *Sex Roles, 20*, 245 - 254.

Changchit, C., Cutshall, R, & Elwood, S. (2008) Perceptions of laptop initiatives: Examining determinant factors of university students for successful implementation. In Lawrence Tomei (Ed.), *Adapting information and communication technologies for effective education* (pp. 88-99). Hershey, PA: Information Science Reference.

Clyde, W., & Delohery, A. (2004) *Guide to classroom technology for mainstream faculty.* New Haven, CT: Yale University Press.

Comber, C., & Colley, A. (1997). The effects of age, gender and computer experience upon computer attitudes. *Educational Research, 39*(2), 123-133.

Dhindsa, H. S., & Shahrizal-Emran (2011). Using interactive whiteboard technology-rich constructivist learning environment to minimize gender differences in chemistry achievement. *International Journal of Environmental & Science Education,* 6(4), 393-414.

GVU Center at Georgia Tech. (1998). GVU's 10th WWW user survey. Retrieved from http://www.cc.gatech.edu/gvu/user_surveys/survey-1998-10/.

Hwang, Y., Suk., Fisher, W., & Vrongistinos, K. (2009). Calibrating a measure of gender differences in motivation for learning technology. *Journal of Instructional Psychology, 36*(3), 259-272.

Joiner, R., Iacovides, J., Owen, M., Gavin, C., Clibbery, S., Darling, J., & Drew, B. (2011). Digital games, gender and learning in engineering: Do females benefit as much as males? *Journal of Science Educational Technology, 20*, 178-185.

Kadijevich, D. (2000). Gender differences in computer attitude among ninth-grade students. *Journal of Educational Computing Research, 22*(2), 145-154.

Kahveci, M. (2010). Student's perceptions to use technology for learning: Measurement integrity of the Modified Fennema-Sherman Attitudes Scales. *The Turkish Online Journal of Educational Technology* 9(1), 185-201.

Kaino, L. M. (2008). Usefulness and enjoyment of using computers in learning. *A gender dimension. Gender & Behaviour, 6*(2), 1841 – 1857.

Keller, J. M. (2010). *Motivational design for learning and performance.* New York: Springer

Kiesler, S., Sproull, L., & Eccles, J. S. (1985). Pool halls, chips and war games: Women in the culture of computing. *Psychology of Women Quarterly, 9*(4), 451–463.

Kirkpatrick, H., & Cuban, L. (1998). Should we be worried? What the research says about gender differences in access, use, attitudes, and achievement with computers. *Educational Technology, 38*(4), 56–61.

Kirkup, G. (1995). Gender issues and learning technologies. British Journal of *Educational Technology, 26*(3), 218–219.

Kim, K. J., Liu, S., & Bonk. C. J. (2005). Online MBA students' perceptions of online learning: Benefits, challenges and suggestions. *Internet and Higher Education, 8*(4), 334-335.

Lang, J. M. (2008). *On course: A week-by-week guide to your first semester of college teaching.* Cambridge, MA: Harvard University Press.

Langin, D. W., Ackerman, P. A., & Lewark. S. (2004). Internet-based learning in higher forestry education. *Unasylva, 216*(55), 39-44.

Lawrence, A. T. (2003) *Challenges of teaching with technology across the curriculum: Issues and solutions.* Hershey, PA: Idea Group Publishing.

Li, N., & Kirkup, G. (2007). Gender and cultural differences in internet use: A study of China and the UK. *Computers & Education, 48*(2), 301.

Lowe, M. (2006). *Beginning research: A guide for foundation degree students.* New York: Routledge.

O'Bannon, B. W., & Puckett, K. (2010). Preparing to use technology: *A practical guide to curriculum integration.* Pearson.

Oppenheim, A. N. (1992) *Questionnaire design, interviewing and attitude measurement.* London: Pinter Publishers.

Peterson, R. A. (1994). A meta-analysis of Cronbach's coefficient alpha. *Journal of Consumer Research, 21*, 381 – 391.

Shashaani, L., & Khalili, A. (2001). Gender and computers: Similarities and differences in Iranian college students' attitudes toward computers. *Computers & Education, 37*(3), 363-375.

Valeberg, B. T., Hanestad, B., R., Klepstad, P., Miaskowski, C., Moum, T., & Rustoen, T. (2009). Cancer patients' barriers to pain management and psychometric properties of the Norwegian version of the Barriers Questionnaire II. *Scandinavian Journal of Caring Sciences, 23*, 518-528.

The Women's Foundation (2006). *The status of women and girls in Hong Kong 2006.* Hong Kong: The Women's Foundation and The Fund for Women in Asia, Inc.

University Grant Council Hong Kong. (2010). *The statistical information of undergraduate student enrolment by gender.* Retrieved from http://cdcf.ugc.edu.hk/cdcf/searchStatisticReport.do; jsessionid=3CF720E18A9C5CBA7A9F748208B238DF

EnviroTech: Student Outcomes of an Interdisciplinary Project That Linked Technology and Environment

Mary Annette Rose

Abstract

Within technology education, few interdisciplinary models exist that attempt to simultaneously promote the development of environmental literacy and technology assessment skills. EnviroTech, an online professional development project for secondary teachers, was designed to achieve this mission. This report, the second in a series on the project, describes the interdisciplinary content of the EnviroTech project and the impact it had on the students of 18 middle and high school teachers who participated in the project. The curriculum was set against a consumer decision regarding the purchase, use, and disposal of light bulbs. This scenario enabled the examination of environmental processes (e.g., mercury cycle and bioaccumulation), mercury's impact upon human health, and practices and policies regarding the disposal and recycling of mercury-containing lamps. Teachers employed guided inquiry strategies and several assessment tools (e.g., experimentation and life cycle assessment) to help students hone their technology assessment and decision-making skills. Differences between preassessments and postassessments indicated moderate improvements in students' knowledge of technology, environmental processes, and strategies to protect themselves against mercury exposure. Significant changes occurred in students' attitudes with students reporting greater attention to sustainability issues when purchasing and designing products.

Keywords: Sustainability, interdisciplinary, environmental literacy, life cycle assessment (LCA), technology assessment, decision-making, technological literacy.

Introduction

There are compelling reasons for technology and engineering teachers to build their students' "understandings of the effects of technology on the environment" and to develop their abilities "to assess the impacts of products and systems" (International Technology Education Association [ITEA], 2000). Because these are *Standards for Technological Literacy* (STL #5 & 13), advocates of standards-based educational reform argue that curriculum alignment to national standards is a precondition to assuring that expectations for all U.S. students are consistent. Consumer protection advocates argue that students should develop assessment skills in order to make well-informed consumer choices that will enhance their personal health and safety. Proponents of democracy education point out that a responsible citizenry must be able to weigh the risks and benefits of technological choices so they can better exercise their personal civic responsibilities and take collective actions to bring about structural and policy changes.

The ecologist's focus on the dynamism, interconnectedness, and adaptiveness of systems is also compelling. It emphasizes that humans are dependent upon the earth's ecosystems for life-sustaining *ecosystem services* (Bennett, Peterson, & Levitt, 2005), such as decomposing waste, filtering water, and the pollinating of food crops. It underscores that *environmental stewardship*—acting to maintain diverse and productive ecosystems that are sustainable—is in the best interest of promoting healthy people, a healthy economy, and a civil and just society. Proponents of *environmental literacy* argue that we must "prepare students to understand, analyze, and address the major environmental challenges facing the students' State and the United States" (No Child Left Inside of 2009, Sec. 5622). These students will make complex decisions that demand interdisciplinary knowledge and skills to both analyze and assess complex interactions and to negotiate competing priorities.

Although technology educators have forwarded reasoned arguments to "develop environmental literacy within technology education" (McLaughlin, 1994) and "reorient curriculum toward a sustainable center" (Petrina, 2000, p. 214), survey data suggests that practicing technology teachers may not have had sufficient opportunities in undergraduate teacher preparation programs to develop the prerequisite knowledge and skills to adequately address Standards #5 and 13 (McAlister, 2005). To address these issues, a web-enabled professional development project called EnviroTech was implemented during the spring of 2009 that included practicing technology and engineering teachers across the United States. "The mission of EnviroTech was to develop (1) understandings of environmental processes and systems; (2) skills for identifying, analyzing, and assessing the impacts of technology upon the environment; and (3) skills in the use of guided inquiry, an instructional strategy where teachers structure and scaffold the examination of problems and gaps in knowledge" (Rose, 2010, p. 44). This article, the second in a series, describes the content of the EnviroTech project and the results it had on the students of 18 middle and high school teachers who participated in the project. The first article—"EnviroTech: Enhancing Environmental Literacy and Technology Assessment Skills" (Rose, 2010)—described the impact on teachers regarding learning gains, instructional practices, attitudes, and intentions. The project was made possible through a grant funded by the United States Environmental Protection Agency and Ball State University.

An Interdisciplinary Approach

A review of research within environmental education literature shows the positive outcomes of integrating environmental education into the school curriculum in terms of students' academic achievement (National Environmental Education and Training Foundation [NEETF], 2000), proenvironmental actions (Rioux, 2011), and critical thinking skills. For example, Ernst and Monroe (2004) examined the influence of an environment-based course on 9th and 12th grade students' critical thinking skills and dispositions toward critical thinking. The Cornell Critical Thinking Test and California Measure of Mental Motivation instruments were used for gathering data. By employing several control variables, such as pretest scores, GPA, and ethnicity, statistically significant effects of the environmental-based program were found for 9th and 12th grade students' critical thinking skills. In addition, 12th grade students in these programs had statistically higher dispositions toward critical thinking than did students who were not taking the environmental-based course.

Within technology education, few interdisciplinary courses appear to strike a balance between environmental and technological literacy goals. For example, Coppola (1999) took a principled case study approach to the development of *Society, Technology, and Environment*, an undergraduate course once offered at the New Jersey Institute of Technology. The course was developed around six guiding principles, including engaging students in realistic problems within authentic contexts and providing a rational approach to environmental problem solving. Several controversial cases, such as damming the Hetch Hetchy Valley to provide water to San Francisco, were chosen for their power to highlight the complexities and diverse values that people have relative to the environment.

Perhaps, the most common strategy for integrating environmental content into technology and engineering education is establishing a need for and set of realistic constraints for problem solving, engineering design, and technology assessment activities. In fact, the Accreditation Board for Engineering and Technology (ABET, 2011, Criterion 3) requires engineering programs to document that their graduates have the ability to design a product or process to meet desired needs within realistic constraints, including environmental and sustainability constraints.

The *Engineering is Elementary*® curriculum, developed by The National Center for Technological Literacy (NCTL) at the Boston Museum of Science, offers a clear example of using an environmental problem as a context for engineering design. For example, in "The Best of Bugs: Designing Hand Pollinators" (NCTL, 2007) curriculum elementary children encounter a breakdown in the pollination of a flowering plant when pollinating insects are no longer present. Children learn about the need for pollination in the production of food crops and the roles that flowers and insects play in the pollination process. This backdrop sets the stage for children to design and test hand pollinators against the physical constraints established by models of flowers. Evaluation studies of "The Best of Bugs" (Lachapelle & Cunningham, 2007) provided evidence from both teacher and students that this integrated curriculum enhances both environmental and technological understandings.

In Technology Use and Assessment, an online course at Ball State University, graduate students collaboratively examine processes and techniques for assessing and forecasting the real and potential impacts of technology on the environment, human health, and society. The purpose of these activities is to inform policy decisions. Many environmental issues have served as the focus of these assessments, such as the following:

> [During] the fall of 2005, the contract fictitiously originated from the U.S. Senate Committee on Energy and Natural Resources and requested a well-researched technology assessment of the energy opportunities presented by American roofs. The assessment of this issue sparked inquiry into the green-house effect, energy efficiency, micro-climates, electric power grid, battery technology, housing design, rain water run-off, solid waste, photovoltaic and solar thermal technology, and green roof technology. (Rose & Flowers, 2008, p. 6)

At the high school level, students in some Virginia schools may take Technology Assessment as the final course in the Design and Technology Program sequence (Virginia Department of Education [VDOE], 2012).

The EnviroTech Project

The development of the EnviroTech project was guided by several principles, including the examination of an authentic problem with rich environmental concepts and principles, exposure to life cycle thinking, a focus upon inquiry to shape learning experiences, and a respect for the autonomy and personal agency of teachers and their students.

An Authentic Problem

The EnviroTech Project was cast against one of the most complex environmental issues of the 21st century: the interactions between the carbon and mercury cycles on planet earth and an electrical system that is powered by fossil fuels. It started with innovation. In the late 1870s, Thomas Edison and Francis Upton developed a durable incandescent light bulb that heated a carbon filament within a vacuum (Consolidated Edison, Inc., n.d.). Recognizing that the light bulb would not be a commercial success without a system to power it, Edison developed and installed the first coal-fired electric generating and distribution system to light the streets of New York City in 1882 (U.S. Energy Information Administration [EIA], 1995).

The average U.S. home contains about 40 light sockets, and lighting accounts for about 20% of the electric bill (Energy Star®, 2006). "In 2010, 45% of the Country's nearly 4 trillion kilowatt hours of electricity used coal as its source of energy" (EIA, 2011a) emitting an estimated 2.4 billion metric tons of carbon dioxide (EIA, 2011b) and 48 tons of mercury into the atmosphere (U.S. Department of Energy [DOE], 2009). Collectively switching to more efficient lamps and increasing energy-conserving behaviors should reduce carbon and mercury emissions to the atmosphere. The lighting energy efficiency standards set within the Energy Independence and Security Act of 2007 (Public Law 110-140, Subtitle B) makes significant progress in assuring that inefficient lamps, such as incandescent lamps, will be removed from the U.S. marketplace by 2014. However, the more complex issues of how to influence consumer behaviors—conserve electricity and keep mercury-containing lamps from municipal landfills—and minimize carbon and mercury emissions from power plants are far more elusive. What once were seemingly simple decisions, such as purchasing and disposing of a light bulb or flipping an electrical switch, take on global significance as people learn more about the material cycles that occur on earth.

Environmental Concepts and Principles

Material cycles, also known as biogeochemical cycles, refer to the natural occurring processes that transport, transform, and store materials through living organisms (animals and plants), the air, water, and land (Smil, 2007). Carbon quickly circulates between the biosphere and atmosphere through basic processes of photosynthesis, respiration, deposition, and combustion, but it moves on a geological time scale when forming rocks (Harrison, 2003). After millions of years, carbon, mercury, and other materials become stored in minerals, such as coal and petroleum. Burning coal releases these materials into the atmosphere.

Mercury that is released into the atmosphere eventually returns to soils and waterways primarily through a process of wet deposition (U.S. Environmental Protection Agency [EPA], 2007). Microorganisms in soils and water consume this mercury and transform it into methylmercury, a neurotoxin. Larger organisms ingest the smaller ones, and eventually the mercury moves up the food chain and bioaccumulates in top predators, including fish, loons, mink, otter, and killer whales. In large doses, exposure to methylmercury can cause "death, reduced reproductive success, impaired growth and development, and behavioral abnormalities" (EPA, 2007, p. 0-3). People are exposed to mercury by consuming contaminated fish or breathing mercury vapors. Exposure can result in brain and nervous system impairment, especially to a developing fetus, infants, and children (Agency for Toxic Substances and Disease Registry [ATSDR], 1999).

The material cycle may be imbalanced by increasing the rate at which these materials move from storage sinks to being in flux. Combusting coal at electrical power plants increases the rate and volume of carbon dioxide (0.0007 Mt/kWh, EPA, 2011) and mercury (0.012 mg/kWh, Energy Star®, 2010) that is emitted into the atmosphere. Increased concentrations of carbon dioxide in the atmosphere trap the thermal energy emitted by the earth and contribute to the rise in surface temperature (National Aeronautics and Space Administration [NASA], 2012), to the acidification of the ocean (U.S. National Oceanic and Atmospheric Administration [NOAA], n.d.), and to changes in our global climate.

Life Cycle Thinking and Inquiry

During a school semester, 19 EnviroTech teachers, guest speakers, and project staff interacted in five synchronous online webinars to build their understanding of environmental processes, inquiry, and technology assessment. All learning experiences were guided by two essential questions that established a connection between a personal decision and an authentic environmental problem:

- How might replacing incandescent lamps with compact fluorescent lamps (CFL) impact the environment and society?

- What strategies might individuals and communities use to reduce the negative impacts of replacing incandescents with CFLs? (Rose, 2010, p. 44)

The instruction and resources provided to teachers encouraged them to adopt guided inquiry, conduct controlled experiments with lamps (Rose, 2009a), and apply life cycle assessment (LCA) as a framework for learning (Rose, 2009b). LCA involves looking both upstream and downstream at each major phase of a product's life cycle, including extraction of raw materials from the environment, design and production, packaging and distribution, use and maintenance, and disposal (Scientific Applications International Corporation, 2006). After bounding the LCA study, the first task is to take an inventory of the inputs and outputs – the energy, materials, water, solid wastes, and atmospheric emissions – of each phase of a product's life cycle. Next, the assessor seeks evidence of the human and ecological effects of these inputs and outputs and then forecasts these impacts into the future. Finally, the user interprets these results to make more informed decisions. The results of an LCA are used by legislators to better inform the development of policies and by business leaders to inform changes to products, processes, or operations. By using LCA as a framework for learning, the hope was that students would develop systemic ways of thinking about the relationships among human decisions, technology, and the environment.

Results of the EnviroTech Project

As evidenced by pretests and posttests, EnviroTech teachers improved their understanding of environmental processes, reported substantial-to-extensive gains in knowledge relative to mercury deposition and bioaccumulation, and were likely to use guided inquiry, experimentation, and life cycle assessment in the future (Rose, 2010). But, if the ultimate goal of professional development programs for teachers were to enhance student achievement (Fishman, Marx, Best, & Tal, 2003), then the value of the EnviroTech Project should be examined relative to student outcomes.

Sample and Procedure

During March and April of 2009, middle ($N = 10$) and high school ($N = 8$) teachers invited their 6th-12th grade students ($N = 380$) and their parents/guardians to participate in an evaluation study of the EnviroTech Project per an approved protocol. As a token of appreciation for participating, students and their parents were offered a $5.00 purchase card. Parents and students who elected to participate mailed the consent form directly to the university; teachers were not aware of who elected to participate.

Immediately before and after implementing the guided inquiry experience, teachers administered the same test, Impacts of Technology, to their students. The instrument assessed students' understandings of key environmental, technological, and technology assessment concepts and principles, as well as items to assess attitudes and levels of commitment to environmental stewardship. This researcher-produced instrument was validated by three external experts, including those with backgrounds in environmental education, technology assessment, and environmental assessment, and it was checked for readability by two technology teachers.

At the end of the school year, after all grades had been recorded, participating teachers mailed to the researcher the assessment forms of students for whom informed consent had been received. Of the 380 invitations distributed to students, 126 students were given parental permission to participate in the study. Of these, only 96 (25% of 380) sets of assessments were usable for matched-pair (pre and post) analyses. As indicated by Table 1, 70% of student participants were from middle school classrooms, and 65% were male.

Student Learning Activities

EnviroTech teachers customized and implemented inquiry-learning experiences with their students to address the aforementioned essential questions. A content analysis of teachers' end-of-project teaching portfolios documented the use of a variety of instructional strategies, including experimentation with lamps (68%), energy calculations (32%), life cycle assessment (25%), force field analysis (11%), and forecasting (11%). Some students conducted surveys to discover how people disposed mercury-containing lamps, others welcomed a lamp recycler and a physician as guest speakers in their classroom, and one visited a fish hatchery to emphasize the bioaccumulation of mercury in the food chain.

Student Results

Knowledge changes. Fourteen test items probed students' understandings about mercury and human health, environmental processes, technology, and technology assessment methods. A Wilcoxon signed-ranks test was employed to examine the differences between pretests and posttests for all 14 multiple-choice knowledge items (Table 2); analyses showed a statistically significant difference between pretest and posttest (Z = -7.531, $p < .000$). Further analyses (Table 3) revealed that the percentage of correct responses increased for 12 of 14 knowledge items. From pretest to posttest, the largest increase occurred in students' ability to identify coal-fired power stations as the largest source of mercury pollution (up 55%). There were also important gains related to human health; an additional 50% of students recognized that eating contaminated fish was the most common way that people are exposed to mercury, and an additional 33% could explain that mercury impairs the brain and nervous system. Furthermore, there were significant gains related to environmental processes with students' understandings of bioaccumulation up 34%, and deposition up 22.9 %. Students also learned important lessons about technology, including how a CFL works (up 43.7%) and how mercury is reclaimed from fluorescent tubes through a process of retorting (up 37.5%).

Two items showed a decrease in the percentage of correct responses on the posttest. The validity of these items is in question. EnviroTech instruction characterized the energy efficiency of a lamp as lighting efficacy and offered the test item responses as formulas. This characterization may have confused students regarding energy conversion efficiency (ratio of energy out to energy in) and lighting efficacy (i.e., luminance divided by electrical power). The item assessing CFLs as household hazardous waste is probably indicative of the

Table 1. Characteristics of Student Participants in the EnviroTech Evaluation Study

Level	Grade	Male (f)	Female (f)	TOTAL by Row	TOTAL by Level
High School	12	6	0	6	
	11	4	4	8	
	10	12	1	13	29
	9	1	0	1	(30%)
	Unknown Grade		1	1	
Middle School	8	17	10	28	
		Unknown sex = 1			67
	7	17	16	33	(70%)
	6	5	1	6	
TOTALS		62 (65%)	33 (34%)		96 (100%)

Table 2. Statistical Comparison of Student's Combined Pretest & Posttest Knowledge Items

	Md[1]	IQR	Wilcoxon Signed-Rank Test	Asymptotic Significance (2-tailed)
Pretest	4.6	3.73	-7.531	.001
Posttest	8.2	5.82		

[1]Calculated from grouped data.

inconsistencies in state regulations regarding the disposal of fluorescent lamps. For instance, the Massachusetts Mercury Management Act "bans the disposal of products containing mercury in trash, starting May 1, 2008" (Massachusetts Department of Environmental Protection, n.d.), whereas in most states no such laws exist; however, consumers are encouraged to take fluorescent lamps to a household waste collection point.

There was also strong evidence that students learned how to protect themselves from exposure to mercury if a fluorescent lamp breaks. Students were asked how much they agreed with the following statement: "When a fluorescent lamp breaks, immediately vacuum the area." A statistically significant difference (Z = -4.380, $p < .000$) was found between pretest (11% correct) and posttest (55% correct). Student responses to the following open-ended item also supported this conclusion: "Describe three actions you should take when a compact fluorescent bulb or fluorescent tube breaks." Analysis of student responses revealed that 66% (61 of 93) of students would correctly begin cleanup by airing out and vacating the room several minutes before attempting to collect broken parts.

Student attitude assessment. Test items were also included to gauge changes in students' attitudes regarding the potential impacts of technology and the criteria they used when making purchase and design decisions. Comparisons between pretests and posttests yielded two statistically significant differences: students became more keenly aware that the products they buy may impact the environment (Z = -2.872, p = .004) and the way these products are disposed of can make people sick (Z = -3.393, p = .001).

Given current initiatives to infuse engineering design into K-12 education, the cluster of six items which assessed changes in students' purchase and design criteria (Table 4) should be of interest to technology and engineering educators. All items – energy consumption; recyclability; time for material breakdown in landfills; harm to people or animals; and affect water, air, and soil – showed statistically significant improvements from pretest to posttest. In addition, students were asked to rank-order the top three traits that were the most important to them when buying a light bulb for their bedroom. As indicated in Table 5, pretest rankings placed *nontoxic* as the highest ranked trait, with *energy efficiency* in fourth position. However on the posttest, energy efficiency and nontoxic were ranked in 1st and 2nd position, respectively. This data suggests that students will consider the environmental impacts of their future actions as they make design decisions in technology laboratories and in the marketplace. It may also indicate a stronger commitment to purchase energy-efficient products and reduce purchases of toxic materials.

Table 3. Percent Comparison of Students' Pretest & Postest Knowledge Items

Knowledge Items	Pretest % Correct	Posttest % Correct	Difference	Rank
Largest source of mercury pollution in U.S.	16.7	71.9	55.2	1
How humans are exposed to mercury	16.7	66.7	50	2
How a CFL works	29.2	72.9	43.7	3
Retorting: Capture chemical in spent lamp	16.7	54.2	37.5	4
Bioaccumulation and food chain	27.1	61.5	34.4	5
Mercury impairs brain and nervous system	47.9	81.2	33.3	6
Why replace incandescents with CFLs	52.1	85.3	33.2	7
Electricity generated by burning coal	20.8	51.6	30.8	8
Mercury deposition	27.1	50.0	22.9	9
How to dispose of spent fluorescent lamp	53.1	76.0	22.9	9
Technology assessments are used to…	14.6	36.5	21.9	11
Life cycle analysis: Identifying impacts	36.5	50.0	13.5	12
Energy efficiency of a light bulb	30.2	22.1	-8.1	14
CFL is household hazardous waste	86.5	78.1	-8.4	15

Table 4. Comparison of Purchase & Design Criteria on Students' Pretests and Posttests

When you purchase or design a product, how often do you think about the following issues?	Pretest[1] Median[2]	IQR	Posttest Median	IQR	Z	p (2-tailed)
How much energy it uses?	2.4	.75	4	1.75	-2.502	.012
Whether it can be reused/recycled?	3	2	3	1.0	-3.642	.000
How quickly materials breakdown in landfill?	2	2	3	2.0	-4.043	.000
How it might harm people?	3	2	4	2.0	-4.933	.000
How it affects water, air, and soil?	3	2	4	2.0	-4.389	.000
How it affects animals?	3.5	1.75	4	2.0	-3.760	.000

[1] Responses ranged from "Always (+4), Often, Sometimes, Rarely, and Never (0)".
[2] Calculated from grouped data.

Table 5. Comparisons of Student Ranked Purchase Criteria for Light Bulbs

	Pretest Rank	Pretest Frequency	Posttest Rank	Posttest Frequency
Nontoxic	1	31	2	25
Long Life	2	21	3	16
Price	2	21	3	16
Energy Efficiency	4	16	1	35
Color & Shape	5	7	5	4
Total		96		96

Conclusion

EnviroTech, an online professional development project for teachers, aimed to improve their knowledge of environmental processes and their skills regarding guided inquiry and technology assessment. The decision of whether to replace incandescent lamps with compact fluorescents served as an authentic consumer decision around which teachers planned and implemented an inquiry-based learning experience with their students. In so doing, students examined lighting technology and the mercury cycle while learning how to use different techniques, such as experimentation and life cycle assessment, to assess the impacts that mercury has on the environment and human health.

Assessments and teaching portfolios indicate that EnviroTech teachers significantly improved their understanding of environmental processes, expanded their instructional strategies for assessing the impacts of technology, and reported strong intentions to integrate sustainability principles into their teaching (Rose, 2010). The merit of professional development for teachers, perhaps, is better judged by the impact the initiative had on student outcomes. Twenty-five percent (96 of 380) of middle and high school students impacted by the project agreed to participate in the evaluation study reported here. Given the small convenience sample, these results may not be representative of the students who were affected by the project. The diverse set of learning experiences implemented by teachers, such as experiments, life cycle assessments, surveys, and guest speakers, also limits conclusions that can be drawn regarding the inquiry strategies.

As evidenced by students' pretest and posttest assessments, knowledge gains were evident relative to environment and technology, especially in regards to identifying coal-fired power plants as the major source of mercury emissions, identifying the consumption of contaminated fish as the primary route by which people are exposed to mercury, and understanding how a CFL works, how bioaccumulation happens, and that mercury impairs brain functions. Furthermore, statistically significant changes occurred in students' attitudes. Students reported greater attention to sustainability issues when purchasing and designing products, including energy consumption, recyclability, time for material breakdown in landfills, harm to people or animals, and ways these products might affect the water, air, and soil.

There are several compelling arguments for technology and engineering teachers to strive to simultaneously enhance students' environmental and technological literacy, including the goal of helping technology and engineering students meet Standards 5 and 13 of the STL (ITEA, 2000). Assessing the impacts of technology on the environment requires advanced understanding about technology, ecosystems, and environmental processes, as well as skills to identify and forecast these impacts. Few instructional models and resources exist to help teachers address these standards, and even fewer have been tested. Curriculum developers need to select accessible environmental problems and carefully craft assessment tasks that expose students to the environmental processes of which people are a part. The EnviroTech project, with its examination of lighting decisions, coal-fired electricity generation, and the mercury cycle, provides one example of weaving together these complex issues. However, we have much to learn about how to use technology assessment tools, such as life cycle assessment, forecasting, and force field analysis, and how to infuse sustainability principles into technology and engineering instruction. We need research-based evidence about the learning processes students use to assess the impact of technology on the environment. In the face of complex environmental problems, we must learn how to facilitate a student's ability to conduct inquiry, synthesize knowledge and skills from a variety of subject areas, and make informed decisions that lead to environmentally sustainable actions.

Dr. Mary Annette Rose is an associate professor in the Department of Technology at Ball State University, Muncie, Indiana. She is a Member-at-large of Epsilon Pi Tau.

"Special thanks to Susan Londt for her assistance in coordinating the EnviroTech Project."

References

Accreditation Board for Engineering Technology [ABET]. (2011). General Criteria 3. Student outcomes. *Criteria for accrediting engineering programs, 2012 – 2013.* Retrieved from http://www.abet.org/engineering-criteria-2012-2013/

Agency for Toxic Substances and Disease Registry [ATSDR]. (1999). Toxicological profile for mercury. Center for Disease Control. Retrieved from http://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=115&tid=24

Bennett, E. M., Peterson, G. D., & Levitt, E. A. (2005). Looking to the future of ecosystem services. Ecology in global scenarios: Feedbacks and the future. *Ecosystems, 8*(2), 125-132. Retrieved from SpringerLink at http://www.springerlink.com/content/v1688353t27k6852/

Consolidated Edison, Inc. (n.d.). A brief history of Con Edison. Retrieved from http://www.coned.com/history/electricity.asp

Coppola, N. W. (1999). Greening the technological curriculum: A model for environmental literacy. *Journal of Technology Studies, 25*(2). Retrieved from http://scholar.lib.vt.edu/ejournals/JOTS/Summer-Fall-1999/PDF/Coppola.pdf

Energy Independence and Security Act of 2007. U.S. Public Law 110-140. Retrieved from http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_public_laws&docid=f:publ140.110.pdf

Energy Star®. (2006). Energy Star® qualified light bulbs: 2006 partner resource guide. Retrieved from http://www.energystar.gov/ia/partners/manuf_res/CFL_PRG_FINAL.pdf

Energy Star®. (2010). Frequently asked questions: Information on compact fluorescent light bulbs (CFLs) and mercury. Retrieved from http://www.energystar.gov/ia/partners/promotions/change_light/downloads/Fact_Sheet_Mercury.pdf

Ernst, J., & Monroe, M. (2004). The effects of environment-based education on students' critical thinking skills and disposition toward critical thinking. *Environmental Education Research, 10*(4), 507-522.

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education, 19*, 643-658.

Harrison, J. A. (2003). The carbon cycle: What goes around comes around, *Visionlearning, EAS-2* (3). Retrieved from http://www.visionlearning.com/library/module_viewer.php?mid=95

International Technology Education Association [ITEA] (2000). Technology for all Americans project. *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author.

Lachapelle, C. P., & Cunningham, C. M. (2007). Engineering is elementary: Children's changing understandings of science and engineering. *Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition.* Retrieved from http://www.mos.org/eie/pdf/research/asee_2007_students_understandings.pdf

Massachusetts Department of Environmental Protection. (n.d.). Summary: Massachusetts Mercury Management Act, [Chapter 190 of the Acts of 2006]. Retrieved from www.mass.gov/dep/toxics/laws/hglawfax.doc

McAlister, B. K. (2005, April). *Are technology education teachers prepared to teach engineering design and analytical methods?* Paper presented at the 2005 International Technology Education Association Conference, Kansas City, Missouri.

McLaughlin, C. H., Jr. (1994). Developing environmental literacy through technology education. *The Technology Teacher, 54*(4), 30-34.

National Aeronautics and Space Administration [NASA]. Goddard Institute for Space Studies. (2012, January, 19). Research News: NASA finds 2011 ninth warmest year on record. Retrieved from http://www.giss.nasa.gov/research/news/20120119/

National Center for Technological Literacy [NCTL]. (2007). *The best of bugs: Designing hand pollinators.* Boston, MA: Museum of Science, Engineering is Elementary.

National Environmental Education and Training Foundation [NEETF]. (2000). *Environment-based education: Creating high performance schools and students* (Washington, DC: Author). Retrieved from http://www.neefusa.org/pdf/NEETF8400.pdf

U.S. National Oceanic and Atmospheric Administration [NOAA]. (n.d.). What is ocean acidification? PMEL, Carbon Program. Retrieved from http://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F

No Child Left Inside Act of 2009, H.R. 2054. Retrieved from http://www.opencongress.org/bill/111-h2054/text

Rioux, L. (2011). Promoting pro-environmental behavior: Collection of used batteries by secondary school pupils. *Environmental Education Research, 17*(3). 353-373.

Rose, M. A. (2009a). Assessment conundrum: CFLs, lighting efficacy, & mercury. Retrieved from http://envirotech.iweb.bsu.edu/instruction/CFL_Experiment.pdf

Rose, M. A. (2009b). Impacts of technology on the environment: Resources for decision making. Retrieved from http://envirotech.iweb.bsu.edu/instruction/LCA_Rose_April.pdf

Rose, M. A. (2010). EnviroTech: Enhancing environmental literacy and technology assessment skills. *Journal of Technology Education, 22*(1), 43-57. Available from http://scholar.lib.vt.edu/ejournals/JTE/v22n1/pdf/rose.pdf

Rose, M. A., & Flowers, J. C. (2008). Technology assessment: A graduate course to build decision-making skills. *Proceedings of the 2008 Conference of the American Society for Engineering Education.* Available from http://www.asee.org/

Petrina, S. (2000). The political ecology of design and technology education: An inquiry into methods. International *Journal of Technology and Design Education, 10*, 207-237.

Smil, V. (2007). Global material cycles. *The encyclopedia of earth.* Retrieved from http://www.eoearth.org/article/Global_material_cycles

Scientific Applications International Corporation. (2006, May). *Life cycle assessment: Principles and practice.* U.S. Environmental Protection Agency (Contract EPA/600/R_06/060). Retrieved from http://www.epa.gov/nrmrl/std/lca/pdfs/600r06060.pdf

U.S. Department of Energy [DOE]. (2009). Mercury emission control R&D. Retrieved from http://www.fossil.energy.gov/programs/powersystems/pollutioncontrols/overview_mercurycontrols.html

U.S. Energy Information Administration [EIA]. (1995). Coal data: A reference. U.S. Department of Energy. Retrieved from http://tonto.eia.doe.gov/FTPROOT/coal/006493.pdf

U.S. Energy Information Administration [EIA]. (2011a). Electricity explained: Electricity in the United States. Retrieved from http://www.eia.gov/energyexplained/index.cfm?page=electricity_in_the_united_states

U.S. Energy Information Administration [EIA]. (2011b). Table 3.0 Emissions from energy consumption at conventional power plants and combined-heat-and-power plants, 1999-2010. Retrieved from http://www.eia.gov/electricity/annual/pdf/table3.9.pdf

U.S. Environmental Protection Agency [EPA]. (1997). Mercury study report to Congress. Volume I: Executive Summary (EPA-452/R-97-003). Retrieved from http://www.epa.gov/ttn/oarpg/t3/reports/volume1.pdf

U.S. Environmental Protection Agency [EPA]. (2007). How mercury enters the environment. Retrieved http://www.epa.gov/mercury/exposure.htm#1

U.S. Environmental Protection Agency [EPA]. (2011). Green power equivalency calculator. Retrieved from http://www.epa.gov/greenpower/pubs/calculator.htm

Virginia Department of Education [VDOE]. (n.d.). Technology education programs and courses. Retrieved from http://www.doe.virginia.gov/instruction/career_technical/technology/programs_courses.pdf

Economics, Innovations, Technology, and Engineering Education: The Connections

John M. Ritz and P. Scott Bevins

Abstract

Throughout history the success of economies around the world has in large part been influenced by technological growth and innovations. Along with such growth and innovations came higher living standards and an improved quality of life for citizens residing and participating in those economies. However, not all countries were able to grow and develop at the same rate, resulting in considerable differences in economic welfare across populations. As nations around the world address the 21st century, economic growth and prosperity for some nations will depend upon how well their citizens are equipped and motivated to seek new technological discoveries and innovations or participate in the supply chain for the production of such new innovations. Such decision making by individuals will be influenced by both economic and political factors existing within each respective country. After providing a description of economic development, the researchers analyze the current economic conditions in several advanced and developing countries and regions around the world, identifying factors that impact the development in those areas. In the remainder of the article, the focus is placed on the skills needed for 21st century workers and the role technology and engineering education might play in eroding the gaps in skill sets required for developing a workforce, thus moving a country forward in development and affluence.

Keywords: Economics, Innovation, Technology and Engineering Education, 21st Century Skills

Economic Growth and Development

Economic growth is important for the well-being of people and nations. According to Herrick and Kindleberger (1983) "economic growth means more output, and economic development implies not only more output but also different kinds of output than were previously produced, as well as changes in the technical and institutional arrangements by which output is produced and distributed" (p. 21). That is, economic development encompasses new innovation and technological improvements and discoveries, leading to growth in real output and higher living standards. In short, economic growth implies the increased capacity or ability to produce either more goods or provide more services for which consumers are willing and able to buy. Factors contributing to economic growth include additional resources, innovations, and increased labor productivity.

Economic growth is measured in terms of the standard of living or per capita real gross domestic product (GDP), yielding the real monetary value of final goods and services produced for each individual in a given year. Although there is no guarantee that each individual will have the means to acquire that monetary amount, increasing living standards will provide greater opportunities for populations to succeed. Higher living standards mean more goods and services are produced for consumption, and sales revenues, employment, and personal income increase. As more goods and services are produced for consumption, economic welfare or satisfaction gained from the consumption of those goods and services is assumed to increase. Per capita real income is a better indirect measure of economic welfare or well-being than per capita real GDP, because it reflects more closely the average purchasing power of the individual. Consequently, growth rates, as exhibited by percentage changes in real income, provide a better indirect estimate of improvement in the quality of life.

Changes in living standards occur from variations in either real GDP or population. If the population grows at a faster rate than real GDP, mathematically, goods and services would be spread more thinly across all individuals. Historically, countries developing the fastest were those classified as capitalist nations having market-oriented economies, the G7 nations – Canada, France, Germany, Italy, Japan, United Kingdom, and the United States. Those economies provided greater opportunities for individual success, whether a person engaged in risk taking through entrepreneurship or elected to work for someone else. As a result of economic and political freedoms within those seven countries, technological breakthroughs and improvements flourished. The right to own and to transfer property provided incentives for individuals to invent, to create, and to be productive. “Private property ensures that producers can appropriate the returns from efficient use of resources to satisfy consumers” (O’Driscoll, 2005, p. 33). Most of the countries that are considered to be capitalist nations would be more appropriately classified as authoritative capitalist nations, such as the Pacific Rim countries of South Korea, Taiwan, Singapore, and Japan. Even though those countries promote private ownership and enterprise as in capitalism, government heavily influences how the *basic* or *fundamental economic questions* of their economy are answered – what goods and services are produced; how they are produced; and for whom they are produced or who consumes them – as opposed to being derived from the voluntary interaction and exchange among buyers and sellers in the market system (Sievert, 1994).

Countries that have economic systems characterized by public property/enterprise and extreme government involvement in answering the *basic economic questions* would be classified as authoritarian socialist or communist nations, and these include the former Soviet Union, North Korea, and China (to some extent). However, China has made significant strides in moving its economy away from the extreme classification of communism by “allowing people to own, buy and sell private property” (Smith, 2008, para. 11). As a result, China has become the second largest economy in size and first in the rate of economic growth (Yanping, Lifei, & Leung, 2010). Relative to the United States, China’s real GDP in 2010 was equivalent to 28% of America’s real GDP ($6,515.86 billion and $14,657.80 billion, respectively) (International Monetary Fund [IMF], 2011).

The Global Economy

As nations address the 21st century, their economic and political systems become increasingly important in determining how well their workforces, and thus their companies, are able to compete globally. Natural geographic boundaries that had previously protected countries from global competition have been eroded by the world’s information network. The free and rapid exchange of information has reshaped both labor and product markets, making them more symmetrical in nature as opposed to asymmetrical. Producers and consumers are now able to obtain similar information about goods and services and employment opportunities. In order to succeed, companies must be quick to adjust and adapt to market changes. Strategic planning and decision making must be iterative in nature; that is, the reevaluation of decision outcomes must be made quickly, in days or weeks not months. According to Herman (2002), leadership must:

- Sense the territory for emerging opportunities and hazards;
- Respond rapidly with converged effort and resources;
- Innovate and keep moving; and
- Maintain [their] balance in a rhythm between emergence and convergence (focusing sufficient attention and resources to accomplish a result). (p. 9)

The ease and manner by which companies are able to follow such strategic objectives rests heavily on the freedoms extended to them through not only their respective country’s economic system, but also via systems existing elsewhere. Given the current advances in technology and innovations, companies can be lured or enticed more easily to locate or re-locate to other countries where bureaucracy, labor conditions, and production and distribution costs are more appealing. Such micro and macro policies and decisions impact the respective country’s real output as well as that of the world.

At present, economists and central banks around the world are at odds about whether inflation exists or if they can acknowledge it exists, fearing that inflation would further stifle their respective economies by reducing exports to other countries. Given the slow recovery from the financial global crisis of 2008-09, the developed countries have been hesitant to increase interest rates, fearing another economic downturn, arguing if food and energy prices are excluded, inflation is low. Since the crisis, economic growth in the developing and emerging economies has outpaced that of the developed countries, substantiating why many of those countries have elected to increase interest rates. In addition, some developing countries have chosen to expand the use of government subsidies for the populous, as a means of calming any unrest (United Nations, 2011).

Ironically, part of the upward pressure on prices is an indirect effect of developing economies around the world, most notably from China's economic growth and policies. As countries develop globally, the cost of labor and of other inputs or factors of production increases, leading to higher relative prices for goods and services. As workers demand higher wages in developing nations, the prices of goods and services in each respective country relative to the prices in other countries increase. As wages increase, workers have more purchasing power and thus, greater ability to shop for alternatives.

In 2012, 85% of the world's real output was supplied by the regions of Europe, North America, and Asia and Oceania (see Table 1). Since 1980, countries within the region of Asia and Oceania have collectively outpaced the other regions in the growth of real GDP and per capita real income, predominately due to China's increase from $216 billion to $4,504 billion in real GDP and from $220 to $3,353 in per capita real income (see Tables 1 and 2).

As countries address the 21st century, the degree to which each succeeds globally will depend upon how much of an emphasis each one places on the development of human capital. As with private enterprise, countries must seek to maximize their returns on their investments by developing human capital through appropriate education and workforce training; such education and training should be not only aligned with current industry needs, but they should also provide a building block from which labor can adjust and adapt workforce skills to a constantly evolving economy.

Today's labor and product markets differ greatly from those of one or two centuries ago. When individuals enter today's workforce, they realize the jobs they were trained for most likely will not last until retirement. The information highway enables buyers and sellers to quickly acquire information, process that information, and respond to it, creating a fast-paced and continuously changing global economy. "In the future, people will worry far less about how safe their current job is and far more about where their next job will be coming from" (Frey, 2011, para. 2).

Assessing and comparing the value of education and its impact on economic growth across countries is difficult given the differing economic, political, and institutional components or policies of each. Previous attempts have

Table 1. Real Gross Domestic Product and Per Capita Income for Regions of the World

	RGDP (billion $s)			Per Capita Real Income ($s)		
	1980	2012	% Change	1980	2012	% Change
North America	$6,402	$14,842	131.8%	$25,424	$42,575	67.5%
Latin America	$1,540	$3,589	133.0%	$4,275	$5,959	39.4%
Europe	$8,414	$15,381	82.8%	$16,798	$28,044	66.9%
Former Soviet Union	$902	$1,323	46.6%	$3,489	$4,691	34.5%
Asia & Oceania	$3,849	$15,073	291.6%	$1,596	$3,987	149.8%
Middle East	$679	$2,012	196.4%	$4,852	$6,743	39.0%
Africa	$465	$1,320	183.8%	$994	$1,254	26.2%
World	$22,251	$53,539	140.6%	$5,068	$7,745	52.8%
Developed	$17,083	$34,834	103.9%	$22,360	$37,594	68.1%
Developing	$3,735	$16,278	335.8%	$1,151	$2,916	153.5%
Former Centrally Planned	$1,434	$2,427	69.3%	$3,764	$6,000	59.4%
Emerging Markets	$2,914	$12,744	337.3%	$1,191	$3,435	188.3%

*Real GDP and real income are in 2005 U.S. dollars.

From "Real Historical Gross Domestic Product (GDP) and Growth Rates of GDP for Baseline Countries/Regions (in billions of 2005 dollars) 1969-2012," by the United States Department of Agriculture (Economic Research Service), 2012. Retrieved from http://www.ers.usda.gov/Data/Macroeconomics/ and "Real Historical Per Capita Income and Growth Rates of Real Income Per Capita for Baseline Countries/Regions (in billions of 2005 dollars) 1969-2012," by the United States Department of Agriculture (Economic Research Service), 2012. Retrieved from http://www.ers.usda.gov/datafiles/International_Macroeconomic_Data/Historical_Data_Files/HistoricalRealGDPValues.xls produced mixed and often contradictory results (Fatehi, Demeuova, & Derakhshan, 2009; Lee, 2010; & Permani, 2009). However, the focus of this article is neither to measure the value of education nor to measure the impact of education on the economic growth of individual countries. The focus is to assess economic conditions of several advanced and developing countries and regions around the world, to identify factors that impact the development in those areas, to identify both technical and soft skills needed for 21st century jobs, and to project the role technology and engineering education might play in closing the gaps in skill sets required for moving a workforce, and thus a country, forward in development and affluence. The countries used in this study were selected from the top four producing regions of the world: Europe, North America, Asia and Oceania, and Latin America. Countries from the region of Asia and Oceania included China, Japan, Malaysia, South Korea, and Taiwan. Peru was chosen from Latin America and the United States from North America. Europe was analyzed as a group.

China

China's growth of approximately 2000% and 1400% in real output and per capita real income over the past three decades has positioned that country among the economic leaders of the world (see Table 2). In 2012, China's real GDP accounted for 30% of overall production from Asia and Oceania and 8% of world production, which increased from 1% to 8.4% since 1980, respectively (United States Department of Agriculture, Economic Research Service [USDA ERS], 2012a, 2012b). Machinery and transportation equipment, miscellaneous manufactured articles (cement, chemicals, fertilizers), and manufactured goods (footwear, toys, electronics, railway cars, space vehicles, and satellites) were China's top export categories in 2010, accounting for approximately 89% of total exports (United Nations, 2010).

As China tightens its economy through contractive monetary and fiscal policies in an effort to curtail inflation, sustaining the rate of economic growth witnessed in recent years will, in the short run, depend on continued growth in consumption or household spending from heavy job creation and in the long run, on the success of educating its future workforce (The Economist Intelligence Unit [EIU], 2010). As of 1996, 70% of students eligible for secondary school were enrolled, an increase from 2% in 1949. Higher education has not experienced such success; approximately 11% of those eligible were enrolled in the late 1990s, which has the potential for problems because more than 25% of people with college degrees began retiring in 2010. Disparities among educational standards are widespread throughout China, occurring at all three levels of education: primary, secondary, and postsecondary. Not only has funding been uneven across provinces, as a

Table 2. Real Gross Domestic Product and Per Capita Income for Selected Countries

	RGDP (billion $s)			Per Capita Real Income ($s)		
	1980	2012	% Change	1980	2012	% Change
United States	5,834	13,584	132.8%	$25,675	$43,219	68.3%
Peru	47	127	167.2%	$2,740	$4,285	56.4%
Europe	8,414	15,381	82.8%	$16,798	$28,044	66.9%
China	216	4,504	1982.0%	$220	$3,353	1426.3%
Japan	2,412	4,690	94.5%	$20,647	$36,823	78.3%
South Korea	163	1,081	564.2%	$4,270	$22,133	418.3%
Taiwan	78	466	494.5%	$4,394	$20,066	356.7%
Malaysia	31	188	509.9%	$2,290	$6,443	181.3%

*Real GDP and real income are in 2005 U.S. dollars.

From "Real Historical Gross Domestic Product (GDP) and Growth Rates of GDP for Baseline Countries/Regions (in billions of 2005 dollars) 1969-2012," by the United States Department of Agriculture (Economic Research Service), 2012. Retrieved from http://www.ers.usda.gov/Data/Macroeconomics/ and "Real Historical Per Capita Income and Growth Rates of Real Income Per Capita for Baseline Countries/Regions (in billions of 2005 dollars) 1969-2012," by the United States Department of Agriculture (Economic Research Service), 2012. Retrieved from http://www.ers.usda.gov/datafiles/International_Macroeconomic_Data/Historical_Data_Files/historicalRealPerCapitaGDPValues.xls percentage of the country's GDP, it actually declined during the 1990s (Narayan & Smyth, 2006).

Japan

Although Japan's real output and per capita real income grew by $2,278 billion and $16,176, respectively since 1980, the increase in real output from developing economies in the region and around the world reduced the country's percentage of contribution to the region and to the world (see Table 2). In 2012, Japan's real GDP accounted for 31% of real output in Asia and Oceania and 9% of world production, down from 63% and 11%, respectively since 1980 (USDA ERS, 2012a, 2012b). Machinery and transportation equipment (motor vehicles and ships), manufactured goods (classified mainly as electronics equipment and machine tools), and chemical and related products (textiles, processed foods) were the top export categories in 2010, accounting for nearly 83% of total exports (United Nations, 2010).

The Japanese economy suffered greatly because of both the financial crisis of 2008 and the physical destruction left by the devastating earthquake and tsunami of April 2011. In addition to these catastrophic events, the country must confront labor shortages during the next two decades, the result of an aging population, a declining birth rate, a decreasing labor force participation rate for those of age 34 or less, and falling demand for labor. In 2005, Japan's birth rate was 1.3, 0.8 less than the 2.1 rate needed for population replacement. Japan entered the 21st century with the workforce growing at a negative rate, -0.46% (Matsukura, Ogawa, & Clark, 2007; Worthley, MacNab, Brislin, Ito, & Rose, 2009).

Malaysia

Even though Malaysia's real output has increased $157 billion since 1980, a growth rate of approximately 510%, the country's output as a percentage of regional production increased only 0.4%, from 0.8% to 1.2% (see Table 2). However, the increase of $157 billion in real GDP improved its standing in the world by 0.3%, from 0.1% to 0.4% of the world's real GDP. The living standard, as measured by per capita real income rose by $4,153, from $2,290 to $6,443 (USDA ERS, 2012a, 2012b). Machinery and transportation equipment; mineral fuels, lubricants, and related materials; and inedible crude materials (tin, timber) (excluding fuels) and animal and vegetable oils, fats, and waxes were the top export categories in 2010, accounting for approximately 71% of total exports (United Nations, 2010).

Since achieving independence in 1957, Malaysia has worked diligently to improve its education system, realizing that economic growth requires an educated citizenry. "The overall thrusts for educational development in Malaysia [are] based upon increasing access to education, increasing equity in education, increasing quality in education and improving efficiency and effectiveness of education management" (Dolhan & Ishak, 2009, p. 16). Unlike China, whose GDP has increased dramatically in large part due to its exports, Malaysia's growth in output has resulted from both increased production in "high technology equipment" by private enterprise as well as increased household consumption or spending on final goods and services produced at home (Rady, 2010).

South Korea

South Korea's growth rate of 564% in real GDP and 418% in per capita real income positioned the country in both categories among those countries and/or regions selected for this study (see Table 2). Such growth in real output increased the country's output contribution from 4 to 7% among producers in Asia and Oceania and from 0.7 to 2% among world producers (USDA ERS, 2012a, 2012b). Machinery and transportation equipment, manufactured goods classified chiefly by material (steel), and chemical and related products (beverages, lubricants) were the top export categories in 2010, accounting for roughly 80% of total exports (United Nations, 2010).

South Korea exited the Korean War in 1953 as one of the most underdeveloped countries in the world, with per capita income of $65. In 2010, however, South Korea's economy was the 12th largest in the world, an increase from the 29th largest in 1969. Per capita income increased over 26,000% to approximately $17,175. Some attribute such economic growth to General Park Chung-Hee's authoritative regime and practice. Through "five-year economic plans," Chung-Hee targeted technological and chemical industrialization as the main recipients of government resources and assistance. As a result, businesses in "electronics, machinery, chemicals, and other industries" (shipbuilding, telecommunications, automobiles) were born, leading to dramatic increases in global exports (Boateng, 2011, p. 18).

Taiwan

Although Taiwan's increase in real GDP accounted for an increase of only 0.5% among world producers, $78 billion to $466 billion, the population witnessed an increase in the standard of living of $15,672, from $4,394 to $20,066 (see Table 2). Among regional producers in 2010, Taiwan's real GDP accounted for 3% of overall production, increasing from 2% since 1980 (USDA ERS, 2012a, 2012b). Machineries and electrical equipment (electronics and information technologies, computers, armaments), basic metals and articles (cement, textiles), and precision instruments, clocks and watches, and musical instruments were the top export categories in 2009, accounting for nearly 66% of total exports (Ministry of Economic Affairs, Department of Statistics, 2011).

Since the 1980s, four Asian economies, China, India, South Korea, and Taiwan, have discovered their comparative advantages in the high-tech, global information market, South Korea and Taiwan in hardware production, and India and China in software production. As of 2006, Taiwan controlled 86% of the market for notebook computers and had made significant gains in the production of "cable modems, servers, and telecommunications equipment" (Shie & Meer, 2010, p. 3).

During the last decade, Taiwan has sought to improve its higher education to compare more favorably to systems around the world. The global economy has forced Taiwan to think in terms of internationalization; that is, higher education and workforce development or training must address global supply and demand for goods and services as well as for labor (Chin & Ching, 2009). Increased emphasis has been placed on technological literacy education and technological and vocational education. In 2009, the "Technological and Vocational Education Reform Project" was introduced with the intended consequences of producing skilled, specialized, competitive workers (Lee, 2010). Measuring the success of these efforts is made difficult by the current global downturns in economic activity. However, as economies begin to expand, it will become clearer as to whether workers' skills are better matched with industry demands.

Peru

Over the past thirty years, Peru's economy has maintained its ranking in the production of real output among Latin American producers as well as world producers, accounting for 3.5% of total production among Latin American producers and 0.2% of world production in both 1980 and 2010. During those 30 years, Peru's real GDP and per capita real income increased from $47 billion to $127 billion and from $2,740 to $4,285, respectively (see Table 2) (USDA ERS, 2012a, 2012b). Inedible crude materials (iron ore, cement) (excluding fuels), animal and vegetable oils, fats, and waxes; commodities and transactions not classified elsewhere (coffee, cocoa, glass, natural gas); and food, live animals, beverages, and tobacco were the top export categories in 2010, accounting for nearly 69% of total exports (United Nations, 2010).

In the last two years, Peru's economy has come through the recent financial crisis in much better shape than many industrialized nations of the world. The country's economy expanded 9.2% in April 2010, 9.3% in May 2010, and 11.9% in June 2010 (Business Monitor International [BMI], 2010). In addition, Standard and Poor's upgrade of "Peru's long-term external sovereign debt rating to BBB on August 30 [2011] implie[d] the agency believe[d] the country's fiscal health will improve over the next few years" (BMI, 2011, p. 10). However, with nearly one quarter of Peru's GDP being exported (BMI, 2011), markets, such as those in Europe and Asia, could have an impact on its rate of future expansion. To promote economic growth during the last two decades, Peru, along with other Latin American countries, has targeted the younger, poor, and less educated portion of the labor force with abbreviated training programs. As a result, a greater percentage of those receiving such training gained employment, particularly "among women and younger people" (Ibarraran & Shady, 2009, p. 211).

Europe

Although European countries produced the greatest real output in 1980 and 2012 ($8,414 billion and $15,381 billion, respectively), the region's living standard was only 66% and 65% of the U.S. standards and 81% and 76% of Japan's, respectively (see Table 2). In 2012, Europe's real GDP accounted for 29% of world production, a decline of 9% since 1980 (USDA

ERS, 2012a, 2012b). Machinery and transportation equipment, chemicals and related products, and manufactured goods classified chiefly by material (aluminum, iron, steel) were the top export categories for the 27-member states of the European Union in 2010, accounting for approximately 71% of total exports (United Nations, 2010).

News reports in the aftermath of the recent financial crisis continue to indicate grave economic volatility among European Union (EU) nations, often suggesting a collapse of the one-currency system. However, economic problems should have been foreseen as a possibility during early plans/negotiations for moving to one currency. The number of member countries (27) and the large variations in the size of each respective economy have compounded the problems of the recent (or current as claimed by some) recession. Prior to the formation of the EU, each country (particularly smaller ones) was able to affect its exports by influencing its exchange rates through the devaluation of its currency, as is done by China. As a result, countries grew at different rates, and the larger ones grew because of exports (The Economist Intelligence Unit [EIU], 2011). "The trouble was the scale of the imbalances and related capital flows, which exploded in the run-up to the global financial crisis in 2007-08" (EIU, 2011, p. 3). Wasteful government spending has put Greece's economy on the brink of collapse, and poor investment decisions made by private banks have contributed to Ireland and Spain's financial woes (EIU, 2011). Given the size of the European economy and the amount of international trade among member nations and the rest of the world, fiscal or monetary decisions made by the EU have an impact on economies around the world. Since such problems arose, German Chancellor Angela Merkel has worked to convince troubled member nations to not withdraw from the EU and return to their native currency, often an argument in opposition to the preferences of members from her own political party (Boston & Lane, 2011).

The threat of monetary collapse has not only overshadowed the efforts made over the last decade to increase the EU's global competitiveness, but it has nearly derailed their successful pursuit of producing a superior knowledge-based economy with high-tech infrastructure and a well-trained/educated workforce. Instead, the EU has witnessed its economic growth rates slipping in comparison to North America and Asia (Bosworth, Jones, & Wilson, 2008). As a result, greater focus is being placed on vocational education and training (VET). The VET system is expected to reduce the gap between industry needs and worker skills, a result of changes in labor markets and increased democratization among member nations (Viertel, 2010).

United States

Though the economy of the United States has not yielded the greatest rates of growth in real output and per capita real income, the nation has continued to produce the greatest quantity of output of any nation in the world while maintaining the highest standard of living. U.S. production accounted for 26% of the world's output in 1980 and 25% in 2012. A living standard of $43,219 in 2012 was approximately four times the average standard of living for 190 countries ($10,636). The U.S. standard of living ranked 9th among those countries, trailing only Luxembourg, Bermuda, Norway, Iceland, Macau, Switzerland, Denmark, and Sweden, respectively (USDA ERS, 2012a, 2012b). Machinery and transportation equipment, chemicals and related products (aluminum, sulfur, glass, copper, steel), and miscellaneous manufactured items (motor vehicles, appliances, machine tools, toys) were the top export categories in 2010, accounting for approximately 61% of total exports (United Nations, 2010).

As U.S. debt continues to grow at a rapid rate, many economists are hesitant about forecasting much short-term economic growth. In fact, some continue to predict another downturn, particularly if politicians choose not to address out-of-control spending, jeopardizing the nation's credit rating. The national unemployment rate was 7.8% in December 2012, with 47% of those being males 20 years of age and older and 42% being females 20 years of age and older (United States Department of Labor, 2013). The Consumer Confidence Index (CCI) fell from 71.5 in November 2012 to 65.1 in December 2012 (The Conference Board, 2012). This index is derived from five areas:

- Appraisal of present business situation
- Expectations of business situation for the next six months

- Plans to buy an automobile, home, major appliance, or carpet within the next six months
- Vacation intended within the next six months
- Expectations of the inflation rate, interest rates, and stock prices for the next 12 months. (The Conference Board, 2011, pp. 5-6)

Fortunately for the United States, its future appears more promising than that of Europe or China, because "America is still the leader in the kind of cutting-edge technology that expands a nation's long-term economic potential, from renewable energy and medical devices to nanotechnology and cloud computing" (Bremmer & Roubini, 2011, p. 3). In addition, the United States compares better in terms of the supply of future laborers, a result of expected continued immigration, China's "one-child per couple" policy, and Europe's decreasing birthrates and increasing opposition to immigration (Bremmer & Roubini, 2011). The United States must now focus attention on reducing the existing skills gap and aligning education and training with industry needs for the 21st century.

Skills for the 21st Century

Occupations have changed during the past 50 years, particularly those related to business and industry. This change includes positions in labor, supervision/management, and design/engineering. Although the term *laborer* continues to exist, in developed countries, many laborers perform their jobs differently. Fifty years ago labor meant muscle, and for some occupations it still does. Today, most labor requires much more use of the mind than muscle. Industry continues to utilize assembly-line laborers, construction workers, and service technicians, but these occupations require more use of advanced technologies (e.g., computer monitoring, data retrieval and entry, laser measurement, machine operation). Some blue- and white-collar jobs are turning into gray-collar jobs (high-tech technicians) because of the advanced technology that is employed (USLegal, 2012). Many of these skilled workers require degrees beyond high school. In addition, supervisors and managers perform most of their functions in offices without moving onto production floors or job sites. Engineering and design work continues to require problem-solving and creativity abilities, but for design and modeling, computers have replaced most drawing boards and human-fabricated prototype models.

Societies venturing into high-technology economies, such as those emerging in the 21st century, need people with technical skills more than ever. Workers must understand processes, such as designing, forming, cutting, and finishing, but the machines and materials used in the workplace have changed; many machines are automated and a large number of products are made from engineered materials. Workers now need to understand various computer applications that apply to their careers (e.g., computer design, scheduling, inventory, materials ordering, CNC applications, testing, inspection, plus many others specific to the job).

Much of the change has occurred for two reasons – (1) the need for increased productivity and (2) machine replacement of labor due to the skills gap in the workforce, that is, there were too few trained machinists, so programmers replaced these needed skills (machines perform functions, humans push buttons to operate the machines, others program these machines). To increase productivity, industry has needed to do more with less. The less meant machines could select the best material layout options for reducing scrap, draw consecutive images on building plans, and control cutting and shaping without relying totally on human skill.

These changes began in the 1980s and 1990s when industry could not find skilled labor, for example, machinists, bricklayers, welders, and others, so engineers and computer programmers designed machines (work cells) where computers and automation could replace the shortage of skilled workers. If microcontrollers could be programmed to control work, then and today, what might happen to the future?

It is very difficult to determine the technical skills that tomorrow's workforce will require. It will depend upon the people who design the new products and technological systems for producing them in the future. To help one think of jobs of the future, CNBC (Bukszpan, 2011) posted projections of "21st Century Jobs." Those posted do have close relationships with content for K-16 technology and engineering education. These potential jobs are listed in Table 3 and most are currently related to the emerging technologies that we read about or see in the news.

What might K-16 technology and engineering education do to shape its curriculum to include the knowledge and abilities related to the basics for these new careers? What should be taught so learners can explore and see if they have the talents that can be strengthened so they might seek careers of these types?

Technology and Engineering Education

Today, there is no shortage of workers; there is a shortage of skilled workers. American factories need 600,000 skilled workers, such as machinists, craft workers, distributors, and technicians (DePass, 2011). Knowing this, can technology and engineering education programs aid in "skilling" our future workers? Learners will need to know various knowledge and abilities related to processes and systems of conventional and bio-related agriculture, communication and information, construction, energy and power, manufacturing, medical, transportation, and other technologies (ITEEA, 2007). Some of these processes include designing (computer-aided designing), planning (using computer applications), and making (cutting, forming, fastening, finishing, packaging using computer-controlled machines). The key is to have future workers know about the processes of technology and have them develop basics, not all skills, in these abilities. Designing, processing, and developing systems are the keys to the technologies one teaches. Researchers do not project the need for specific technical skills, because machines should be "intelligent" in the future and easy to use if one understands technical processes and systems, and industry can handle this type of development in its workers (Prashad, 2011).

Technology and Engineering Education's Connection to Future Workers

Technology and engineering education teachers must think about skills that students will need to innovate, design, and engineer our futures. Professionals in these subjects need to teach important concepts that are required for citizens to be technologically literate and prepared to move into technical occupations. The U.S. National Academy of Engineering (NAE, 2010) has reported core ideas that need to be embedded into our education systems. The following are the concepts that future workers will need to understand:

- Design
- Systems
- Constraints
- Optimizations
- Modeling
- Analysis
- Communication
- Relationship between engineering and society

Also important for our technology and engineering education programs is the need to develop individuals who are able to think critically and apply what they know to authentic, problem-based scenarios. Teachers must encourage "young people to investigate their current world while contributing to its future. This is the type of education that can be offered through technology and engineering programs, K-20" (Carter, 2011, p. 14).

This idea is supported in *The Employee Handbook of New Work Habits of the Next Millennium* (Pritchett, 1999). Pritchett believes there are job rules for the 21st century. He believes a change in mindset is needed, so one can think and see differently. Carter (2011) connected these ideas to technology and engineering education. She reported what is required:

> [Because] The marketplace simply will not accommodate old belief systems about business, careers, and future occupation development. Thinking from these new

Table 3. Jobs for the 21st Century

Custom Implant Organ Designer	Nanotechnologist
Stem Cell Researcher	Waste Management Consultant
Respiratory Therapist	Organic Food Producer
Nutritionist	Biochemical Engineer
Wind Turbine Technician	Robotics Technician

Source: Bukszpan, D. (2011). 21st Century Jobs. CNBC. Retrieved from www.cnbc.com/id/45874627/21st_Century_Jobs

> angles of reality, STEM education, and technological and engineering literacy, present proactive, not reactive, concepts to the ever-evolving workplace, necessitating a knowledge-based workforce. (p. 14)

If technology and engineering education teachers truly want to contribute to the development of society and its workforce, they need to prepare students with the basic skills they will need for the years ahead. These include: digital-age literacy, inventive thinking, interactive communication, and quality, state-of-the-art results (METIRI Group, 2010). Table 4 illustrates the meaning of these skills. Each will be discussed in relationship to technology and engineering education, K-16.

Workers' Skills for the 21st Century

Digital-age literacy involves many skills and abilities. The one that technology and engineering subjects focus on is technological literacy (ability to use, manage, understand, and assess technology) (ITEEA, 2007). This is the outcome technology and engineering educators should seek in their laboratories. It also involves other basic literacies, such as learning and using reading, writing, and mathematics. Cultural awareness and understanding others and their values are part of this basic education. Computer literacy is included in visual and information literacy. These are the basic literacy requirements of the 21st century. These are what a basic general education and technology and engineering education should include. In the future work will require digital-age literacy skills of all productive workers and citizens.

Interactive Communication

Interactive communications is a skill set that is key to people trusting each other and working together for common causes – it can be called team membership. Working together and supporting each other's ideas can help an organization grow. These skills also can expose cultural divides that must be solved to circumvent complex problems that arise in business and society. Industrial communication problems that have arisen at the corporate levels (e.g., runaway automobiles, deadly chemicals in pet food and toys, nuclear and chemical accidents, energy disasters) continue because profit has become overly important to corporations and their shareholders. Every day people continue to learn the importance of interactive communications related to governments, companies, and consumers. Prosperous companies are open to the public and communicate within. If employees rethink what they know and what others report, and if they work in a collaborative environment, then they arrive at new ideas or innovations. This way personal and social responsibilities are developed (Korhonen, 2003), and companies and consumers reap the benefits.

Quality, State-of-the-Art Results

Another important skill set for 21st century citizens and workers is quality, state-of-the-art results. This implies one can prioritize, plan, and manage oneself and one's work. Workers employ real-world tools to get the job done more efficiently. The results of their work can produce high-quality results. Parenting has removed these responsibilities for youth in some nations, particularly much of the Western world (White,

Table 4. 21st Century Skills

Digital Age Literacy – Today's Balance	• Basic, Scientific, and Technological Literacy • Visual and Information Literacy • Cultural Literacy and Global Awareness
Inventive Thinking – Intellectual Capital	• Adaptability/Managing Complexity and Self Direction • Curiosity, Creativity, and Risk-taking • Higher-Order Thinking and Sound Reasoning
Interactive Communication – Social and Personal Skills	• Teaming and Collaboration • Personal and Social Responsibility • Interactive Communication
Quality, State-of-the-Art Results	• Prioritizing, Planning, and Managing • Effective Use of Real-World Tools • High Quality Results with Real-World Applications

Source: METIRI Group in partnership with The North Central Regional Laboratory. (2010). Retrieved from http://enGauge.ncrel.org and www.metiri.com. These skills resulted from their meta-analysis of other skill reports. The full report can be retrieved from http://ncrel.engauge.org.

2005). Through group work in technology and engineering courses and other subjects, teachers can redefine these skills and put them into practice, so young people will again recognize their importance as individuals, to society, and in the workplace.

Inventive Thinking

Inventive thinking is one of the key skills needed in the 21st century, according to economic and government reports (European Design Innovative Initiative, 2012; Freeman & Soete, 2012; Garcia & Calantone, 2003). Invention/innovation is important to economic development for a country, region, or global environment. It is a skill needed by economies so a country can prosper in the 21st century. Next, inventive/innovative thinking will be explored for its connections between economics and technology and engineering education. It is a major attribute these programs can build upon.

Innovative/Inventive Thinking

Innovative/inventive thinking is a trait that can be taught and coached by technology and engineering educators (Starkweather, 2005). As is described by the National Innovation Initiative (Council on Competitiveness, 2005), innovation is the "intersection of invention and insight, leading to the creation of social and economic value" (p. 38). It is a key to making an economy productive. Innovation is a change "in a product offering, service, business model, or operation which meaningfully improves the experience of a large number of people" (Carpenter, 2010, para. 5). It involves change, product (or model or service), and meaningful alteration of people's experiences.

The Council on Competitiveness (2005) indicated that there are prerequisites for a country to be innovative. Some of these include:

- Educate the next generation of innovators
- Deepen science and engineering skills
- Explore knowledge intersections (e.g., multidisciplinary, STEM)
- Equip workers for change
- Support collaborative creativity.

These prerequisites reflect skills needed for the 21st century (METIRI, 2010).

As added by Starkweather (2005), "innovation improves the quality of lives in countless ways" (p. 28). Following are a few of these ways:

- Offers new forms of convenience
- Offers new products or services
- Improves products or services by making them more affordable
- Is a way to solve the great challenges facing society
- Enables achievement of dramatically higher levels of health
- Develops product options for the aging population
- Finds plentiful, affordable, environmentally-friendly sources of energy
- Spreads demographic approaches
- Helps win the war against terrorism
- Expands access to knowledge. (p. 28)

The smartphone is one of these innovative products that has changed our experiences and expanded business and industry. Ultrasound and MRI are innovations in medicine. Microwave popcorn is an innovation in food processing. GPS farming innovations produce higher yields. Communication systems in automobiles are also innovations. These innovations have created new jobs in ever-expanding economies.

Change is a key to innovation. People need to experience situations where their mind goes into an "energized" feel-good mode. They need to feel how the product or service changes their feelings or aspirations. For teaching innovation, educators want to develop attitudes in students. Thus, educators have students ask questions such as: How can we make a product more useful? Would life be better if we had this product or that system? Educators want students to know that product/service innovations should involve something different that will affect large numbers of people and systems. Innovation sells to those who can afford a new way of doing things. Our technological world has continuously encountered these changes and many innovations will further spur economic growth.

Ruttan (2001) purported that for innovation to occur, natural resources and cultural endowments (research institutions, think tanks, successful companies) are needed. If resources do not exist, they need to be imported. Innovations can occur in all areas of technology. For an innovation to be meaningful, it should change current experiences for people. Smartphones are a major innovation throughout the world. Fewer infrastructures are needed, such as supporting landlines for the system and phone to operate. New medicines to control the spread of HIV are also major changes to the human experience. The key for innovation to work is that it must become a way of thinking both for producers and consumers. It is not only for designers and engineers. Workers at all levels should think innovatively. In order for innovative products to get to the market, all workers must envision possible changes to enhance the products, services, systems, and models they produce, so they might promote further improvements. Such innovative thinking will keep economic growth prospering.

Connections

Through technology and engineering education and explorations in laboratories, teachers can create and deliver programs that enable innovative thinking to develop and prosper. Classes can be set into environments that will necessitate innovative thinking and performance. For example, an instructor could create a problem where learners are divided into teams to design and build self-sustaining gardens that will produce food all year round. What can the learners grow in their garden that will have local appeal? How will the plants be watered? How will the group control for changes in weather? How will they heat and cool a structure that might house the living and growing environment? Will there be a structure that will house the ecosystem? Possibly, on land next to the school building, students might create a sustainable ecosystem with a garden. The technological systems of construction, energy and power, communication and information, agriculture, and bio-related technologies could be employed. Careers in organic food production, biochemical engineering, and nutrition, along with others, can also be explored through this type of teaching.

While conducting research for the creation of the ecosystem, students will need to use digital-age literacy. They need basic literacy to research and calculate the needs for the eco-system. Inventive thinking will be needed to design the system and to solve problems that arise with the designs. Re-thinking will be needed to work around design solutions, so the most efficient systems can be made within engineering and environmental constraints (e.g., structure size, power to operate pumps and heating and cooling systems, costs, life cycles of producing plants). Interactive communications will be needed to review team members' ideas and the way in which they work together efficiently. Quality, state-of-the-art results will need to be kept in focus to have a resulting, operational system.

This is a complex study of technology and engineering, but the solution is a system that can be used in the future by students, the school, and society. The same could be the case in the design of a temporary structure that could be used in a disaster situation. What can be manufactured with materials at hand, can be operational in several hours, and can protect a family of six until permanent structures can be obtained? Many countries have experienced this need in recent times, so the development of such structures should be of high interest to students and develop the skills workers in the 21st century will need.

Teachers' and curriculum designers' thoughts only limit ideas for these types of design problems. The key is to prepare learners for their future, assist them in developing skills needed for the 21st century, and make them consider careers that can aid in building economic development for themselves and their countries.

Summary

Citizens need basics for daily livelihoods, and less developed economies still rely on manual labor for their economies and survival of their people. But where are economies headed with new jobs? Education is an important ingredient for new economies. To get the innovative products that those with discretionary monies will purchase, one needs workers who come up with the new innovations. One needs teams of innovative thinkers, and technology and engineering education can contribute to the production of this intellectual capital. One must re-think and not continue to offer programs that were good for the 20th century. One must change to programs that focus on core technological and engineering literacy and the skills recognized as needed for 21st century citizens.

No longer should technology and engineering education have labs where every student follows the same templates for re-producing a teacher-designed product. Teachers and curriculum designers should create problem situations and have teams of students come up with their own ideas to answer these problems. Technology and engineering education must teach the fundamental skills of the 21st century, digital-age literacy, inventive thinking, interactive communication, and quality, state-of-the-art results. By focusing on these 21st century skills, and integrating these skills with technological and engineering literacy, technology and engineering education should be able to prepare learners to move their economies and workers forward throughout this century.

John M. Ritz is a Professor and Graduate Program Coordinator in the Department of STEM Education and Professional Studies at Old Dominion University, Norfolk, VA. He is a member of the Alpha Upsilon Chapter of Epsilon Pi Tau.

P. Scott Bevins is Director of Institutional Research, University of Virginia's College at Wise, Wise, VA.

References

Boateng, O. (2011, April). The rise of South Korea, a lesson for Africa. *New African*, 18-19.

Bremmer, I., & Roubini, N. (2011, November 12). Whose economy has it worst? *The Wall Street Journal*. Retrieved from http://online.wsj.com

Boston, W., & Lane, M. (2011, November 14). Merkel urges party to help save Euro. *The Wall Street Journal.* Retrieved from http://online.wsj.com

Bosworth, D., Jones, P., & Wilson, R. (2008). The transition to a highly qualified workforce. *Education Economics, 16*(2), 127-147.

Bukszan, D. (2011). 21st century jobs. *CNBC*. Retrieved from www.cnbc.com/id/45874627/21st_Century_Jobs

Business Monitor International [BMI]. (2010). Peru: Growth has peaked, but will remain strong. *Emerging Markets Monitor, 16*(20), 10-10.

Business Monitor International [BMI]. (2011). Peru: Not upgrading sovereign ratings. *Emerging Markets Monitor, 17*(22), 10-10.

Carpenter, H. (2010). Definition of innovation. Retrieved from http://www.cloudave.com/202/definition-of-innovation/

Carter, K. (2011). Occupations of the 21st century. In J. Ritz & P. S. Bevins (Eds.), The connection to the 21st century workforce: Technology and engineering education (pp. 14-21). Reston, VA: International Technology and Engineering Educators Association.

Chin, J., & Ching, G. (2009). Trends and indicators of Taiwan's higher education internationalization. *The Asia-Pacific Education Researcher, 18*(2), 185-203.

The Conference Board. (2011). *Consumer confidence survey technical note.* Retrieved from http://www.conference-board.org/pdf_free/press/TechnicalPDF_4321_1319533202.pdf

The Conference Board. (2012). *The conference board consumer confidence index declines.* Retrieved from http://www.conference-board.org/data/consumerconfidence.cfm

Council on Competitiveness. (2005). *Innovate America*. Washington, DC: Author.

DePass, D. (2011, December 30). American factories cry need for 600,000 skilled workers. *Star Tribune.* Retrieved from http://www.startribune.com/blogs/132063803.html

Dolhan, H., & Ishak, N. (2009). National education policy: Education development master plan – charting the future. *Revista Panamericana de Pedagogia, 15*(2009), 13-32.

The Economist Intelligence Unit [EIU]. (2010). Country report September 2010: China. Retrieved from http://www.eiu.com

The Economist Intelligence Unit [EIU). (2011]. State of the union: Can the euro zone survive its debt crisis? Retrieved from http://www.scribd.com/doc/53647174/Economist-Intelligence-Unit-White-Paper-Can-the-euro-zone-survive-its-debt-crisis

European Design Innovation Initiative. (2012). *Design for growth & prosperity.* Helsinki, Finland: European Commission.

Fatehi, K., Demeuova, G., & Derakhshan, F. (2009). Transitional economies of Central Asia and business education. *Competition Forum, 7*(1), 266-272.

Freeman, C., & Soete, L. (2012). *The economics of industrial innovation.* London: Routledge.

Frey, T. (2011, June 17). Building a rapid job-creation engine. [Web log comment]. Retrieved from http://www.wfs.org/content/building-rapid-job-creation-engine

Garcia, R., & Calantone, R. (2003). A critical look at technological innovation typology and innovativeness terminology: A literature review. *Journal of Product Innovation Management, 19*(2), 110-132.

Herman, S. (2002). From “predictions” to “emergence”: A new fundamental. In S. Herman (Ed.), *Rewiring organizations for the networked economy* (pp. 3-19). San Francisco, CA: Jossey-Bass/Pfeiffer.

Herrick, B., & Kindleberger, C. (1983). *Economic development* (4th ed.). New York: McGraw-Hill.

Hilesnrath, J., Burkitt, L., & Holmes, E. (2011, June 21). Change in China hits U.S. purse. *The Wall Street Journal.* Retrieved from http://online.wsj.com

Ibarraran, P., & Shady, D. (2009). Evaluating the impact of job training Programmers in Latin America: Evidence from IDB funded operations. *Journal of Development Effectiveness, 1*(2), 195-216.

International Monetary Fund [IMF]. (2011). World economic outlook database. Retrieved from http://www.imf.org/external/pubs/ft/weo/2011/02/weodata/index.aspx

International Technology and Engineering Educators Association [ITEEA]. (2007). *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author.

Korhonen, J. (2003). On the ethics of corporate social responsibility – Considering the paradigm of industrial metabolism. *Journal of Business Ethics, 40*(4), 301-315.

Lee, C. (2010). Education and economic growth: Further empirical evidence. *European Journal of Economics, Finance and Administrative Sciences, 23*(2010), 161-168.

Lee, L. (2009). *Technological literacy education and technological and vocational education in Taiwan.* (ERIC Document Reproduction Service No. ED508339).

Matsukura, R., Ogawa, N., & Clark, R. (2007). Analysis of employment patterns and the changing demographic structure of Japan. *The Japanese Economy, 35*(1), 82-153.

Ministry of Economic Affairs (Department of Statistics). (2011). Export by commodity. Retrieved from 2k3dmz2.moea.gov.tw/gnweb/English/Indicator/wFrmEnIndicator.aspx

METIRI Group & The North Central Regional Educational Laboratory. (2010). Twenty-first century skills. Retrieved from http://mcrel.engage.org

Narayan, P., & Smyth, R. (2006). Higher education, real income and real investment in China: Evidence from Granger causality tests. *Education Economics, 14*(1), 107-125.

National Academy of Engineering [NAE]. (2010). *Standards for K-12 engineering education?* Washington, DC: The National Academies Press.

O’Driscoll, Jr., G. (2005). Economic freedom: The path to development. Retrieved from http://www.fee.org/files/docLib/odriscoll.pdf

Permani, R. (2009). The role of education in economic growth in East Asia: A survey. *Asian-Pacific Economic Literature, 23*(1), 1-20.

Pritchett, P. (1999). *The employee handbook of new work habits of the next millennium.* Dallas: Pritchett Publishing Corporation.

Prashad, S. (2011). Need skilled workers? Create your own. *The Globe and Mail.* Ontario: Ontario Business Partnership.

Rady, D. (2010). A study of the major constraints on Egyptian economic growth during the period 1998-2008: A comparison with Malaysia. *Journal of Global Business and Economics, 1*(1), 120-140.

Ruttan, V. (2001). *Technology, growth and development: An induced innovation perspective.* Oxford: Oxford University Press.

Shie, V., & Meer, C. (2010). Is this the Asian century? China, India, South Korea and Taiwan in the age of intellectual capitalism. *Journal of Contemporary Asia, 40(*1), 1-21.

Sievert, D. (1994). *Economics: Dealing with scarcity* (3rd ed.). Wisconsin: Glengarry Publishing.

Smith, V. (2008). Human betterment through globalization. Retrieved from http://www.fee.org/nff/human-betterment-through-globalization/

Starkweather, K. (2005). Innovation, TIDE teachers, and the global economy. *The Technology Teacher, 65*(2), 28-30.

United Nations. (2010). International merchandise trade statistics. Retrieved from http://comtrade.un.org/pb/CountryPagesNew.aspx?y=2010

United Nations. (2011). World economic situation and prospects 2011. Retrieved from http://www.un.org/en/development/desa/policy/wesp/wesp_current/2011wespupdate.pdf

United States Department of Agriculture, Economic Research Service [USDA ERS]. (2012a). Real historical gross domestic product (GDP) and growth rates of GDP for baseline countries/regions (in billions of 2005 dollars) 1969-2012. Retrieved from http://www.ers.usda.gov/datafiles/International_Macroeconomic_Data/Historical_Data_Files/HistoricalRealGDPValues.xls

United States Department of Agriculture, Economic Research Service [USDA ERS]. (2012b). Real historical per capita income and growth rates of real income per capita for baseline countries/regions (in billions of 2005 dollars) 1969-2012. Retrieved from http://www.ers.usda.gov/datafiles/International_Macroeconomic_Data/Historical_Data_Files/historicalRealPerCapitaGDPValues.xls

United States Department of Commerce, International Trade Administration. (2011). Top U.S. trade partners. Retrieved from http://www.trade.gov/mas/ian/build/groups/public/@tg_ian/ documents/webcontent/tg_ian_003361.pdf

United States Department of Labor, Bureau of Labor Statistics. (2013, January 4). The employment situation – December 2012. (Series USDL-13-0001). Retrieved from http://www.bls.gov/news.release/pdf/empsit.pdf

USLegal. (2012). Grey-collar worker. Retrieved from http://definitions.uslegal.com/g/grey-collar-worker/

Viertel, E. (2010). Vocational education for sustainable development: An obligation for the European Training Foundation. *European Journal of Education, 45*(2), 217-235.

White, W. S. (2005). Students, parents, colleges: Drawing the lines. *The Chronicle of Higher Education, 52*(17), B16.

Worthley, R., MacNab, B., Brislin, R., Ito, K., & Rose, E. (2009). Workforce motivation in Japan: An examination of gender differences and management perceptions. *The International Journal of Human Resource Management, 20*(7), 1503-1520.

Yanping, L., Lifei, Z., & Leung, S. (2010, October 21). China's growth cools as inflation accelerates. Bloomberg News. Retrieved from http://www.businessweek.com

Is the Technology a New Way of Thinking?

Mohammed Sanduk

Abstract

In his consideration of thought development, Auguste Comte proposed a three-stage model, in which the mechanism of development may lead to new types of thought. So the process that led to a philosophy of science may be repeated to create a new type of thought. The thought development is attributed to a process of accumulation of challenged but unanswered questions, followed by a decline of interest in that type of thinking.

The science stage presented a huge accumulation of achievements, but at the same time it confronts huge challenges. The present work is a theoretical analysis for what is happening because of these challenges. The author believes that the technology may be regarded as a fourth stage for Comte's model. The technology stage corresponds to globalization as a social stage. Technology has its own methodological way. Owing to the connection between the technology and human need, the development of technology follows a Darwinian evolution model. The process of technology selection that leads to development is the *user selection,* which corresponds to Charles Darwin's *natural selection.*

Keywords: Philosophy of technology, Three-stage model, New scientific spirit, Globalization, Thought evolution, Technology development.

Introduction

The development of human civilization is associated with the development of knowledge. Auguste Comte traced thought development through time and formulated his law of three stages (Comte, 1855). Comte postulated three theoretical stages of development of thought and society: the theological, the metaphysical, and the positive, which correspond to the fictitious, abstract, and scientific ways of thinking, respectively. Each type has a characteristic logic and methodology.

1. The theological stage tries to attribute natural phenomena to personified deities. Thus, explanations of natural phenomena take the form of stories or legends. This stage may have three subdivisions: animism, polytheism, and monotheism.

2. The metaphysical stage uses a rational explanation style; abstract explanations are developed in this stage.

3. The positive stage tries to discover and explain nature according to science and experimental proofs.

Comte (1855) considered social development in a similar set of three stages as well. In his most important work, Comte "explains why the law of the three stages is stated twice. Properly speaking, the law belongs to dynamic sociology or theory of social progress" (Comte, 2008, 4.1). Comte identifies a stage of material development corresponding to each social developmental stage:

- The theological stage may also be called the military stage, and the military may be a feature of a primitive society;

- The metaphysical stage corresponds to supremacy of the lawyers and jurists;

- The positive stage is industrial; industry is based on scientific achievements.

Comte, an engineer, was up to date with scientific developments of the Industrial Revolution of the 19th century. Table 1 shows the two sets of developments, that of thought and that of society.

Table 1. Comte's stages

	Thinking stage	Social stage
1.	Theological stage	Military
2.	Metaphysical stage	Supremacy of the lawyers and jurists
3.	Positive stage	Industrial

In the early years of the last century, there were revolutionary achievements in pure theoretical physics (PTP), including the development of the theory of relativity and quantum physics, which made pure physics the main branch of the modern history of physics. The strong agreement between theoretical predictions and experimental investigations led to great support for that branch of knowledge. The unusually large number of achievements in PTP during the first three decades of the last century motivated Gaston Bachelard's declaration of his new scientific spirit (Bachelard, 1985) or a new philosophy of science. A new type of physical thought based on probabilities of single particles and the accumulation of new achievements were behind his declaration. However, at that time, there were no recognized serious obstructions confronting quantum physics, one of Kuhn's (1962) scientific revolutions.

The present work is a discussion of a possible new phase of thinking, the fourth stage according to Comte's scale. This work is organized as follows:

- An overview of the mechanisms of thought development.
- A review of the present situation of science research.
- Postulation of a new stage, according to the mechanism of development.
- Investigation of the features of this new stage.

This work is not a philosophical study but a study in philosophy. Thus, the approach will not follow the philosophical argumentation. Instead, an analytical approach for the situation of science and technology is followed.

The flow and obstruction model

The development of thought can be explained by either dialectical or evolutionary processes. The materialism proposition states that the mere augmentation of a thing or things produces a change in quality and characteristics and, conversely, that a qualitative change produces a quantitative one (Thalheimer, 1936). Accordingly, the deflection of thought to a new direction may be considered a historical necessity. This process can also be considered using Toynbee's (1987) challenge and response theory. In this model, new types of thinking are responses to challenges.

The change of thought mainstream is somewhat similar to changes in the direction of flow of water due to an obstruction. In this model, "obstructions" develop from an accumulation of challenging questions or unconvincing answers. To represent how the "mainstream" direction changes, Figure 1 represents the types of thought mainstream with different directions of flow.

However, for Comte, "theology declined as it was challenged by scientific spirit, which fulfilled people's need much more effectively" (Pickering, 1993, p. 633). Theological (fictitious) interests declines in favor of metaphysical (abstract) works, and metaphysical interests decline in favor of scientific thought. The decline and challenges might have led Auguste Comte to his proposal of thought development. The diversion of the mainstream thinking to a new type of thinking appears to occur as a result of two types of accumulations:

1. The accumulation of challenged questions (lack of logic). This accumulation works as an obstruction and forces the mainstream to change direction.
2. The accumulation of potential (achievements) to find a new way of thinking. This accumulation is based on the previous achievements of the blocked thinking and provides the potential for the new direction of flow.

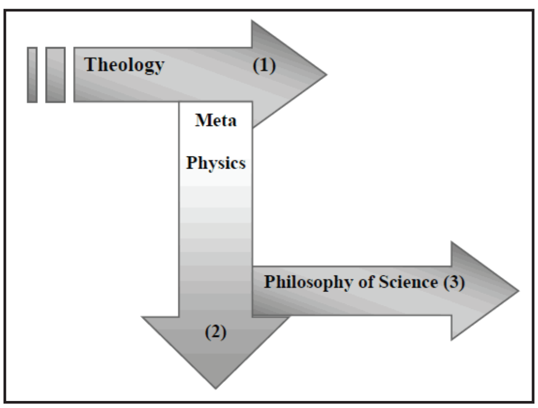

Figure 1. Changing the direction of thought mainstream (as flow) according to Comte's three mentally conceived stages.

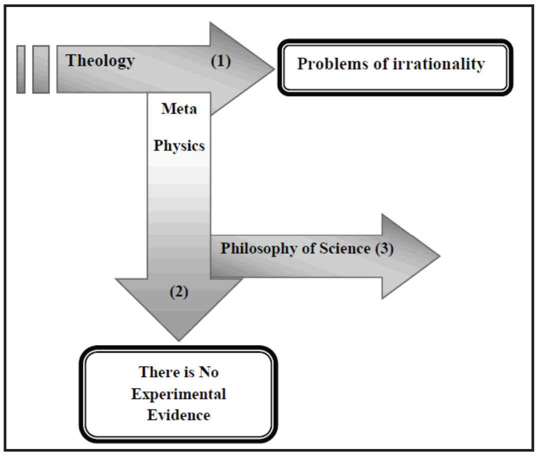

Figure 2. Flow of thought and effect of obstructions.

Figure 1 shows the diversion of thought flow, and Figure 2 represents the flow of thought and the obstruction effect for the three types of thinking. The process of development looks like a mechanism of flow and obstruction. The new stream due to the obstruction is of the new feature.

Pure research and the accumulations

In Europe, the remarkable shift toward scientific thought occurred during the scientific revolution in the 16th and 17th centuries (Shapin, 1998). Science started to change the direction of how people understood nature and started to affect religious belief. Shapin and many other historians (e.g., Lindberg, 1987) insisted on "Science as Religion's Handmaid," referring to Comte's second stage (metaphysics). Science as knowledge occupied the place of religion in providing alternative interpretation of the natural phenomena and provides solution for some of life's problems. Science without applications (without technology) does not have that effect on life developments of society. It may affect the understanding of nature and then social beliefs or social thought; that is quite clear in comparison the social effect of both of Darwin's evolution theory and Marconi's radio invention. The first led to a religious shock, whereas the second improved the quality of life.

Like any new belief or thought, science affects society after any scientific revolution. The historical period that most marks the beginning of science's effect on society was the so-called Industrial Revolution (18th and 19th centuries). That revolutionary era led Comte to the concept of industrial society. The adoption of industry for the science achievements and discoveries led to serious influence of science on society.

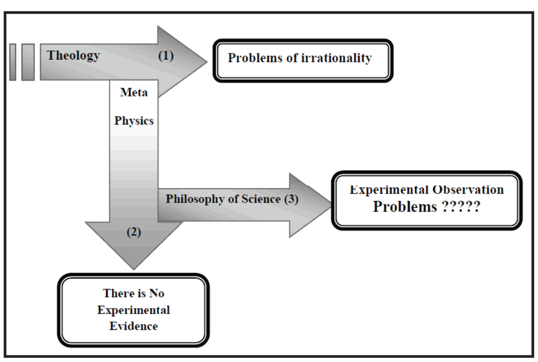

Figure 3. The problems that change thought.

However, during the first half of the 19th century, the scientific environment became more notable and influential than it had been before for many reasons:

- Science was able to explain nature in a more convincing way than either theological or metaphysics theories.
- The benefit, persuasiveness, and applicability of scientific knowledge made scientific studies more favorable and popular than theological or metaphysical studies. Subsequently, most universities turned gradually from theological to scientific studies.
- There were large developments and an accumulation of scientific achievements.

This new type of thought rose as a new challenge to the dominant metaphysical type of thought. It led to slower growth or relative decline in metaphysical (abstract) works and interests compared with the growth of scientific achievements. Then, Positivism became the new direction of thought flow (Figure 2).

Thus, the process of increase and decline may mark an era of a new type of thought. In describing the evolution process, Comte's law identifies only three stages, but these may be followed by many other stages as long as there is accumulation and obstruction.

In conclusion, the advancement and accumulation of scientific achievements led to a new way of thinking (see Figure 3).

New accumulations

Through pure research, scientific developments led to two types of accumulation:

- The accumulation of a huge number of scientifically proven achievements (scientific fact) that describe nature and can be used for many different applications.
- The accumulation of theoretical works without experimental investigation.

There are many philosophical attempts to classify and define sciences. Within science communities, the definition of pure or basic research is controversial, and it is far from the definition of basic science; there is no unified definition (Calvert & Martin, 2001). Here, the focus is on the epistemological and intentional features of research and the definition from the Organisation for Economic Co-operation and Development (OECD). Basic research *"is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view"* (OECD, 1994).

These two accumulations are epistemological in nature. The second accumulation is that of theoretical works that are impossible (at least in the present time) to investigate experimentally. For example, most of the theoretical predictions of PTP in the second half of the 20th century, such as string theory (Schroer, 2008; Smolin, 2006; Woit, 2007), black hole theories, and black matter theories, at different levels (microphysics and cosmological physics) faced and are still facing large obstructions to experimental investigations. Theoretical works accumulate and grow rapidly relative to the level of the slow development of technology of the experimental investigations. As in the example of PTP, either the needed technology is too advanced and sophisticated, or the needed technology is beyond the present level of science (e.g., space travels of superluminal velocity).

These problems are not easily overcome and may form knowledge barriers that lead to *knowledge boundaries* (Sanduk, 2008), as shown in Figure 4. These boundaries resemble ultimate limits at both the microscopic and cosmological levels. Scientists start to confront the feeling their usual probing investigation may be at an end. In PTP, a huge amount of theoretical work is now carried out without investigations, and great numbers of research articles around the world are in need of experimental evidence. These boundaries are neither metaphysical nor faith based.

Edmund Husserl (1970) predicted a crisis of science in his article, "The crisis of the European Sciences," but his point of view was based on intentional phenomenology. Aldous Huxley mentioned limits on studies in his fifth novel in which he wrote in 1931 that "we can't allow science to undo its own good work. That's why we so carefully limit the scope of its researches" (Huxley, 1998, p. 227). In this sentence, Huxley may mean an imposed restriction on research, which is different from the limits mentioned previously.

However, PTP is a good example for the growth and decay of interest in science. In the first decades of the 20th century the great achievements of PTP made it very popular and garnered a great deal of research interest. However, PTP's honeymoon did not continue. Its decline began in the second half of the 20th century. This became noticeable during the 1990s, when pure physics research grants began to shrink, as did students' interests. The decline was quite obvious and continues today (Cressey, 2008).

In addition to the two accumulations of epistemological nature, there is a growth of human demand for a better and comfortable life. Scientists distinguish between pure research and applied research. Applied research aims to solve a particular problem related to direct application. With aid of pure research outputs, applied research can find solutions for human demands. Technology tries to fulfill human needs (de Weck, Roos, & Magee, 2011)

Contemporary technology (like IT, nanotech, genetic engineering . . .) is based on large accumulations of science outputs, which can help in diverse applications and technology. Thus, a large accumulation provides technology with an extremely high potential for rapid growth.

Technology depends on two types of research: basic science studies (which has a high accumulation of achievements) and research & development (R&D), which is adopted and supported by industry, government, and others.

Interest in basic research declines in favor of applied and development research (or R&D),

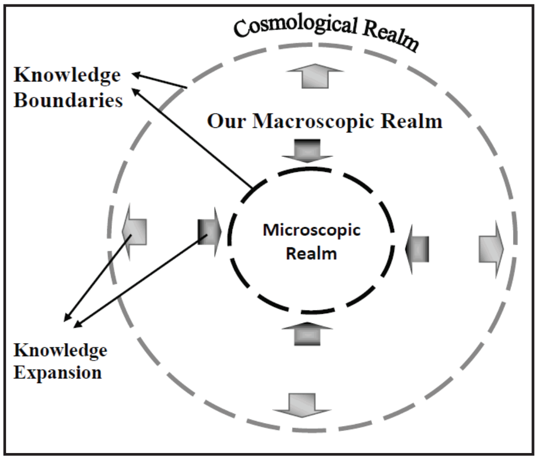

Figure 4. The boundaries of scientific knowledge.

which is clearly observed in developed countries. Figures 5 & 6 show the funding of

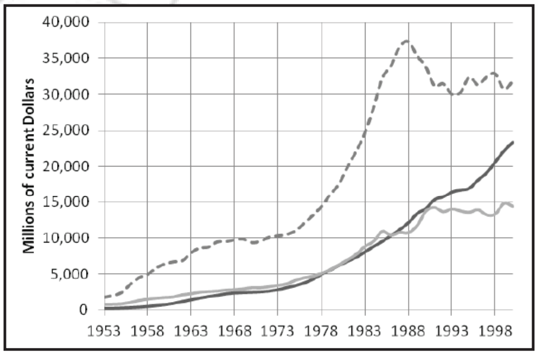

Figure 5. U.S. federal government spending development for the basic, applied and development research (1953-2000) (Science and Engineering, Indicators 2002).

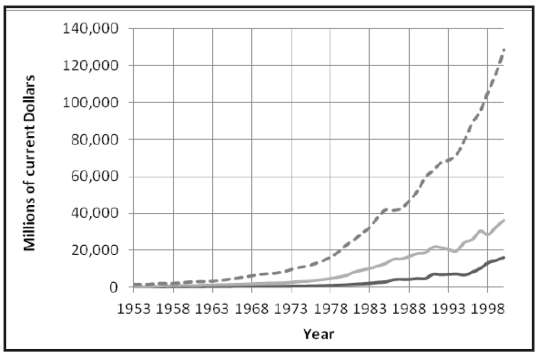

Figure 6. The U.S. industry spending development for basic, applied and development research (1953-2000) (Science and Engineering Indicators, 2002).

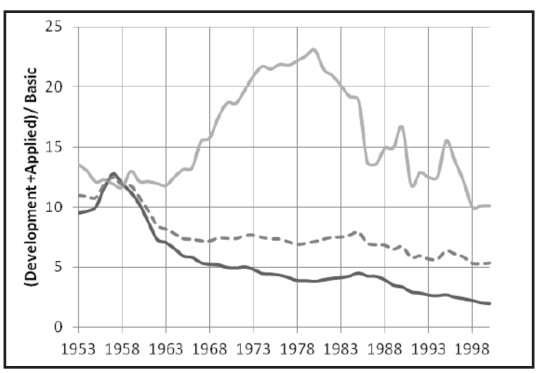

Figure 7. The ratio of U.S. spending on R&D to spending on basic science for both federal government and industry sectors (1953-2000).

research in the United States during the second half of the last century (the period 1953-2000). Interest in basic research supported by industry declined, compared with research on applications and development. Based on these data, Figure 7 shows the ratio of the funding of development and applied research to the funding of basic research. It is obvious that the federal government, rather than industry, tries to support basic science. However, basic research still earns less support than applied research and development. There is no doubt that the vital role of basic research resulted in the federal government's change in its funding policy after 1958. Nevertheless, the balance remained in favor of applied and development research.

Social interest in science may be reflected by the number of graduate students and by employment opportunities. For example, Figure 8 shows the number of earned bachelor's degrees in the United States in different fields during the period 1993-2007. Growth of student

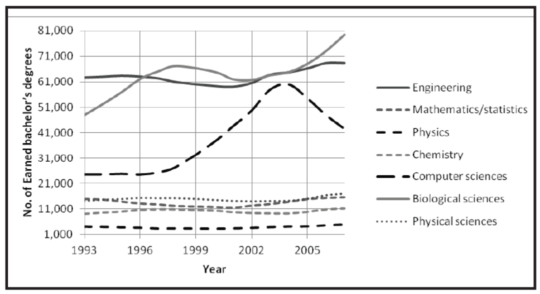

Figure 8. The number of the earned bachelor's degrees in USA for different field at period 1993-2007 (Science and Engineering Indicators, 2010).

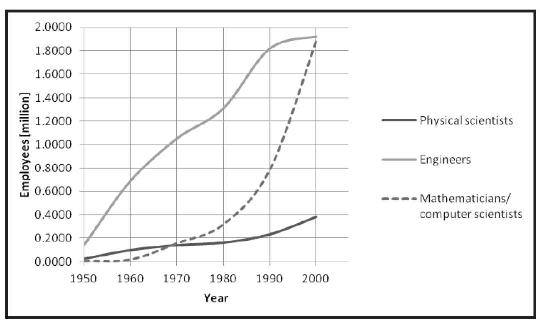

Figure 9. Employees in science and technology in the USA 1950-2000 (Science and Engineering Indicators, 2010).

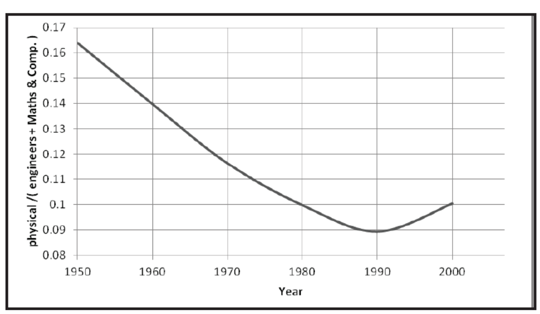

Figure 10. The ratio of physical scientists to engineers, mathematicians and computer scientists.

interest is observed in applied fields, such as engineering, biological sciences, and computer sciences, whereas no such significant growth is shown in the physical sciences, such as physics, chemistry, and mathematics. Tracing historical employment in science and technology shows a growth in engineering and computational jobs relative to physical science jobs (Figures 8, 9, and 10).

The United Kingdom is a similar case. In a 2008 report titled "Review of UK Physics" (Research Councils UK, 2008), the authors concluded the following:

- "There has been a significant decline in recent years of the number of students taking physics at A level (a stage before university) . . . ."

- "Physics has a significant impact on the economy and society . . . . Possibly, the most valuable contribution appears to be physics trained graduates, who are highly sought after in many sectors of the economy."

- "The Panel heard from many sources that more needs to be done to encourage university-based physicists to work more closely with industry . . . . We found that much of the research work in physics that was of direct interest to business was being performed in departments other than physics in the university sector. This has the effect of reducing the number and size of income streams to physics departments . . . "

We focused on the PTP as an example. Yet many branches of sciences are reaching their peak of growth now (like genetic researches), but this is just a growth step similar to what it was like for PTP. The decline is a natural phenomenon. The present pure science situation is similar to that of the decline in metaphysics. Science is the third stage in Comte scale; Does the decline in pure science interest lead to a new deviation in the flow of thinking?

Is there a new fourth stage?

Because there is always a new accumulation and decline, the evolution of thought may lead to many new philosophical phases.

The relationship between science and technology is the relationship between need and knowledge, and historically it is a deep relationship. Following the model of flow and obstruction, a new stream is expected. The previous discussion (the paragraph of *New accumulations*) shows clearly the real observable growth of applied science. That growth is faster than the growth of basic science, and it is more complicated.

Due to the complicated structure of technology (technology is dependent on scientific facts, engineering, politics, trade, etc.), technology develops rapidly as an exponential trend over time. Figure 11 shows the rapid growth of the technology of global ICT and the retardation of others (old technology, like fixed telephone). Mobile technology looks as of exponential trend.

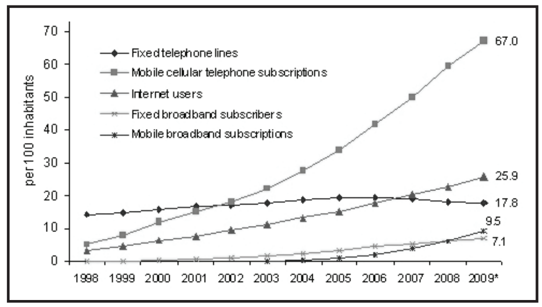

Figure 11. Global ICT developments, 1998 – 2009 (ITU World Telecommunication/ ICT Indicators database, 2009).

The fourth stage is obviously based on science, but it goes beyond science with a more complicated structure. Thus, the next stage is technology (see Figure 12).

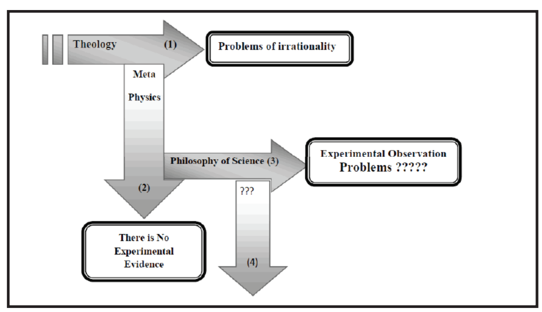

Figure 12. The possible fourth stage.

Philosophy of technology

In the late 19th and early 20th centuries, John Dewey was optimistic about the role of technology and adopted a pragmatic view (McDermott, 1981).

The intensive interest in this type of thinking started around the middle of the last century, when technological achievements appeared to have manifested some serious effects on human society, such as the problems of the World War II, as identified by Martin Heidegger (Heidegger, 1993). The fast growth of technology and its side effects and misuse led to distinguish it from science. The first clear and focused report on the serious role of technology is the "Mount Carmel Declaration" of 1974 (50 Technion, 1974). The declaration insisted on technology without science. It is the first report written and signed by scientists. The declaration warns of the misuse of technology and puts it in the ranks of the threat of human welfare and survival.

Interest in technological thinking was adopted academically, as many philosophers now are considered technology philosophers. Most of the works of these philosophers concern the social or humanitarian effects and history of technology. However, technology is more complicated than these limited considerations. The new generation of engineers and technologists are interested in the philosophical background and the social impact of their works or innovations. Some of them cannot distinguish between the logic of science and the methodology of engineering and technology.

However, due to new applications or science products, a new type of methodology has been effectively implemented since the end of the last century (Sanduk, 2003). Technology is unlike science; it starts with applicable invention. Necessity drives invention, as the age-old maxim states. This drive has no full acceptance by the technology historian (The EMELSON-MIT Program, 2004). In the present work, the drive of invention is regarded as a type of need (to make life easy, to address physiological needs, etc.). Proving a new idea depends on scientific laws, engineering, then industry, trade, politics, sociology, and more, for production, marketing, and so on. Just as science has its methodology, so technology has its own working logic (Figure 13). In his book *Globalization and Technology*, Rajneesh Narula presented a diagram relating R&D to technology and science (Narula, 2003, p. 3).

A distinct type of thinking has been initiated, apart from the philosophy of science. The new type has multidisciplinary features. Although science is characterized by a single type of research, pure research, the R&D of technology includes the following:

- Applied Research
- Product Research
- Manufacturing Research
- Materials Research
- Market Research
- Operations Research.

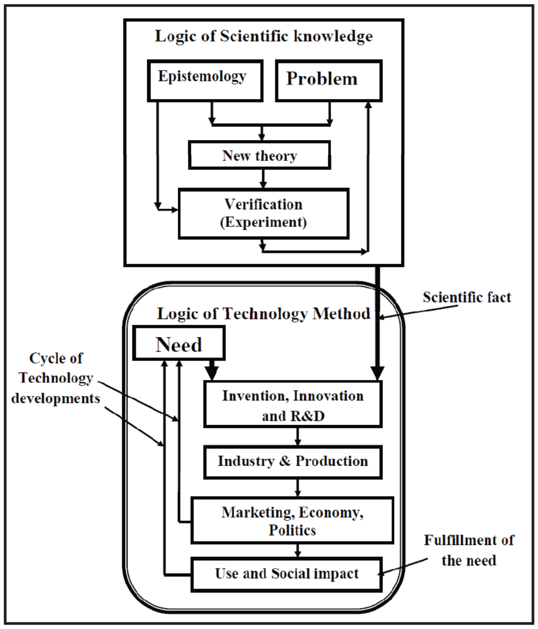

Figure 13. The logic of scientific knowledge and technological methodology.

The technological era is the era of disciplinary mixtures—multidisciplinary or interdisciplinary. It is not a time of separated or isolated sciences.

The development of technology

Technology has its method of work. It is of a circular nature (Figure 13). Modifications or improvements are expected, and technology advancements occur over time for many different reasons. However, in all cases, the aim of modification is to achieve the fulfilment of need; the best technology is that which best meets the need. Therefore, there are many generations of each type of technological invention (e.g., television, computer, pen). The age of each generation depends on the quality of its performance, the social impact, ethics, market conditions, and so on. The selection of the technology invention in this case is a *social selection.*

On the other hand, some technologies became obsolete (see Figure 11), and these

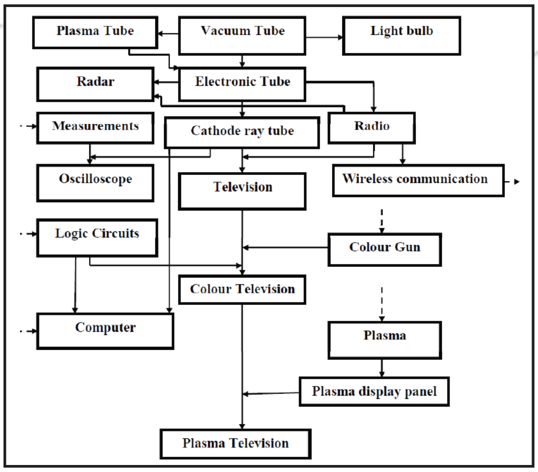

Figure 14. A branch of the vacuum tube family that includes the evolution of the television (Sanduk, 2003).

technologies disappear gradually (or become extinct). Thus, technology development has features that resemble Darwinian evolution. The technology in each step of development will be accepted if it meets the need of that development, as in Herbert Spencer's phrase *"survival of the fittest"* (Peel, 1972). The process of technology selection that leads to development is the social (user) selection, which corresponds to Charles Darwin's *natural selection.*

Scientific development occurs through a revolutionary process, according to Kuhn (1962), whereas technological development takes place through a Darwinian type of evolution. The appearance of a new technological invention resembles an evolutionary jump. With different and multiple uses, it will be circulated in many different developmental ways. Many different generations will branch off from that "grandfather." Figure 14 shows a branch of vacuum tube family and the evolution of the television. It is quite clear that the old members of the family are extinct, while the younger generation continues to develop.

Globalization

Our present societies are not industrial societies; they are more complicated. Technology today is structured in many ways, including industry, economy, politics, and others. The rapid advance of technology creates many types of instabilities (social, personal, global, etc.). The world has become smaller, and any event will receive a rapid response. In 1998, Longworth wrote of the shrinking of the world, "With computer and satellite, currency and stoke traders can do business virtually anywhere at any hour of the day" (Longworth, 1998, as cited in Ramos, 2003, p. 24). Not only have distances decreased but time has shortened as well. *In Globalization and Technology,* the author examines the interdependence of globalization and technology at two levels, the interdependence between locations, and between corporate entities (Narula, 2003). Humanity looks forward to globalization.

Table 2. The modified model of stages

	Thinking stage	Social stage
1.	Theological stage	Military
2.	Metaphysical stage	Supremacy of the lawyers and jurists
3.	Positive stage	Industrial
4.	Technology stage	Globalization

Pascal Lamy of the World Trade Organisation (WTO) defines the globalization as "a historical stage of accelerated expansion of market capitalism, like the one experienced in the 19th century with the industrial revolution. It is a fundamental transformation in societies because of the recent technological revolution which has led to a recombining of the economic and social forces on a new territorial dimension" (Lamy, 2006). This definition suggests that the technology stage corresponds to globalization. Table 2 shows a modified model of Comte's stages. There is no technology without globalization and no globalization without technology; both grow interactively at the same time.

The comparison between Comte's model as shown in Table 1 and the modified model (Table 2) reflects the continuous developments in the thought and society.

Conclusions

The previous discussion shows a decline in interest in pure science and a growth in interest in applied science and technology interests. Regarding Comte's model, we may reach to the following conclusions:

- Technology can be regarded as a fourth stage for a modified Comte's model, following the positive stage.

- The technology stage corresponds to globalization as a social stage.

Thus, the technology has its own way of work and development. Technology methodology is quite different from the logic of science.

Owing to the connection between the technology and human need, the development of technology follows a Darwinian evolution model. The process of technology selection that leads to development is the *social (user) selection,* which corresponds to Charles Darwin's natural selection.

Acknowledgment

The author would like to thank Prof. D. Brandon of Technion-Israel Institute of Technology for supplying a copy of the original document of The Mount Carmel Declaration; thanks also for the National Science Foundation, Division of Science Resources Statistics for their advice on collecting the statistical data. The author would also like to thank the anonymous reviewers for their valuable comments and suggestions.

Dr Mohammed Sanduk is an associate lecturer and visiting academic staff in the Faculty of Engineering and Physical Sciences, Department of Chemical and Process Engineering at the University Of Surrey, UK.

References

Bachelard, G. (1985). *The new scientific spirit* (A. Goldhammer, Trans.) Boston: Beacon Press.

Calvert, J., & Martin, B. (2001) Changing conceptions of basic research? Background Document for the Workshop on Policy Relevance and Measurement of Basic Research, Oslo 29-30 October 2001. www.oecd.org/dataoecd/39/0/2674369.pdf (Accessed 13 October 2011)

Comte, A. (1855/2003). *The positive philosophy of Auguste Comte.* (H. Martineau, Trans.). Vol. I, p. 1. Kessinger Publishing.

Comte, Auguste. (2008). In (E. N. Zalta, Ed.), *Stanford encyclopaedia of philosophy.* First published Wed Oct 1, 2008; substantive revision Thu Jun 2, 2011. http://plato.stanford.edu/entries/comte/ (Accessed 2 June 2011)

Cressey, D. (2008). Government was warned of physics crisis. *Nature.* 16 January 2008.

de Weck, O. L., Roos, D., & Magee, C. L. (2011), *Engineering systems: Meeting human needs in a complex technological world.* Cambridge, MA: MIT Press.

The EMELSON-MIT Program (2004). Historical perspectives on invention & creativity, School of Engineering, Massachusetts Institute of Technology, 15. http://web.mit.edu/invent/n-pressreleases/downloads/history.pdf. (Accessed 30 September 2011)

Heidegger, M. (1993). The question concerning technology (D. Krell, Ed.). (p. 321). New York: *HarperCollins* Publishers.

Husserl, E. (1970). *The crisis of European sciences and transcendental phenomenology; An introduction to phenomenological philosophy* (D. Carr, Trans.). Evanston: Northwestern University Press.

Huxley, A. (1998) *Brave new world.* New York: Harper Perennial Modern Classics, Ch.17.

ITU World Telecommunication/ ICT Indicators database (2009), http://www.ispreview.co.uk/story/2009/10/08/global-mobile-broadband-subscriptions-to-top-600-million.html (Accessed 22 October 2011)

Kuhn, T. (1962). *The structure of scientific revolutions.* Chicago: The University of Chicago Press.

Lamy, P. (2006). Humanising globalization. Geneva, Switzerland: The WTO; [updated 2006 Jan 30; cited 2006 June 1]. Retrieved September 10, 2011, from http://www.wto.org/english/news_e/sppl_e/sppl16_e.htm.

Lindberg, D., (1987). Science as handmaiden: Roger Bacon and the Patristic tradition. *Isis, 78*(4), 518-26.

McDermott, J. J. (1981). *The philosophy of John Dewey. C*hicago: University of Chicago Press.

Narula, R. (2003). *Globalization and technology.* New York: John Wiley and Sons Ltd.

Organization for Economic Co-operation and Development [OECD]. (1994). The measurement of scientific and technical activities: Proposed standard practice for surveys of research and experimental development Paris: OECD (p. 68).

Peel, J. D. Y. (Ed). (1972). *Herbert Spencer: On social evolution.* Chicago: The University of Chicago Press.

Pickering, M. (1993). *Auguste Comte: An intellectual biography,* Volume 1. Cambridge, England: Cambridge University Press, p. 633.

Ramos, C. (2003). *Globalization and Technology.* Manila: Rex Bookstore, Inc., p. 24.

Research Councils UK (2008). Review of UK physics, panel. Chaired by Professor Bill Wakeham, Swindon.

Sanduk, M. I. (2003). Philosophy of technology, *Philosophica,* 1 (V), pp. 11-20.

Sanduk, M. I. (2008). Physics limitations and the philosophy of technology, *Workshop on Philosophy & Engineering, WPE2008,* The Royal Academy of Engineering London, November 10-12 2008. Retrieved October 13, 2011, from www.raeng.org.uk/societygov/philosophyofeng/pdf/abstract_papers.pdf

Schroer, B. (2008). String theory the crisis in particle physics and the ascent of metaphoric arguments. *IJMPD 17*, 2373-2431.

Shapin, S. (1998), *The scientific revolution.* Chicago: The University of Chicago Press.

Science and Engineering, Indicators (2002). Volume 2– *Appendix tables,* Chapter 4, Retrieved October 16, 2011, from http://www.nsf.gov/statistics/seind02/pdf_v2.htm

Science and Engineering Indicators: 2010 (2010), *Appendix tables,* Table 2-12, Retrieved October 16, 2011, from http://www.nsf.gov/statistics/seind10/appendix.htm

Smolin, L. (2006). *The trouble with physics: The rise of string theory, the fall of a science, and what comes next.* Boston: Houghton Mifflin Harcourt. Retrieved September 2, 2011, from www.rcuk.ac.uk/documents/reviews/physics/review.pdf

50 Technion Wunsch International Symposium Ethics in an age of pervasive technology, (1974). *The Mount Carmel declaration on technology and moral responsibility*, Technion – Israel Institute of Technology, Haifa.

Thalheimer, A. (1936). *Introduction to historical materialism—The Marxist view.* New York: Covici Friede.

Toynbee, A. (1987). *A study of history,* Vol. 1: Abridgement of Volumes I-VI. New York: Oxford University Press.

Woit, P. (2007). String theory and the crisis in particle physics, Gulbenkian Foundation *Conference on Is Science Near Its Limits?* 25-26.

Student Professional Development: Competency-Based Learning and Assessment

Jacqulyn A. Baughman, Thomas J. Brumm, and Steven K. Mickelson

Abstract

This case study examines the implementation of competency-based learning (CBL) and assessment as a measure of student professional development. Students enrolled in an industrial technology undergraduate course at a Midwestern university participated in this study. Based on the degree program outcomes, the "top five" course competencies were identified, and their key action items were assessed using an industry-based, 360-degree assessment process. Significant differences in the average initial and final assessed values were used to determine professional development gains. Findings showed that self-assessed professional gains were achieved, self-assessed results were higher than peer results, and overall peer assessments indicated aggregate gains in professional development. This case study provides a foundational framework for further research studies in competency-based learning and assessment.

Keywords: competencies, professional development, competency-based assessment

Background

Because most college-aged students are entering adulthood, the attitudes, interests, values, and character development that underlie their behaviors may not be at a professional level (Hayward, Noonan, & Shain, 1999). Student development has been described as "the ways that a student grows, progresses, or increases his or her developmental capabilities as a result of enrollment in an institution of higher education" (Rodgers, 1990, p. 27), and is about becoming a more complex individual (McEwen, 2005). The complementary theory used to explain and understand student development allows educators to "proactively identify and address student needs, design programs, develop policies, and create healthy environments that encourage positive growth in students" (Evans, Forney, & Guido-DiBrito, 1998, p. 5). Existing student development theories are very much interrelated (Gardner, 2009). Psychosocial development theories are concerned with the content of development including growth or change related to how students view themselves and their abilities, the relationships they have with others in their lives, and the future direction of their lives (Chickering & Reisser, 1993). This encompasses adult development and career development (McEwen, 2005).

Competencies are the result of integrative learning experiences in which skills, abilities, and knowledge interact to form learning bundles that have a currency related to the task for which they are assembled; interest in competencies is accelerating throughout the world (R. Voorhees, 2001). Until recently, competencies have been discussed from the demand side of employment, and consideration has been given primarily to the needs of employers. Competency models can be used by the supply side of the labor market as well, such as a learner or student, incumbent worker, or hopeful and expectant new employees applying for a position to achieve job stability (Ennis, 2008). Competency-based models enjoy an obvious connection to aspirational student learning statements, because they shift the focus from instructional delivery to student performance (A. Voorhees, 2001). Competency-based learning (CBL) involves redefining program, classroom, and experiential education objectives as competencies or skills and focusing coursework on competency development (Brumm, Mickelson, Steward, & Kaleita, 2006).

Postsecondary education has become progressively responsive to the needs of business and industry, where learning is closely tied to competencies and performance-based assessment of those competencies (Gardner, 2009). Building a bridge between the educational paradigm that depends on traditional credit hour measures of student achievement and the learning revolution can be found in competency-based approaches (R. Voorhees, 2001). These competencies are crucial for students before, during, and after attending postsecondary institutions (National Center for Education Statistics [NCES], 2002). In a 2002 report, the U.S. National Postsecondary Education Cooperative Working Group on Competency-Based Initiatives determined three reasons why it is important to implement competency-based initiatives in colleges and universities:

> One main reason is that specific articulations of competencies inform and guide the basis of subsequent assessments at the course, program, and institutional levels. Secondly, specific competencies help faculty and students across campus, as well as other stakeholders such as employers and policy-makers, to have a common understanding about the specific skills and knowledge that undergraduates should master as a result of their learning experiences. Assuming that faculty use a formal process to get feedback about what the competencies should be, then stakeholders are more likely to accept and value them. Third, specific competencies provide directions for designing learning experiences and assignments that will help students gain practice in using and applying these competencies in different contexts. (NCES, 2002, p. vii)

The definition of workplace competencies is the application of knowledge, skills, attitudes and values, and behaviors (Ewell, 1984). These competencies are directly measurable through actions or demonstrations of the existence of those competencies in the individual. Thus the opportunity to gain practice in the application of competencies and focused reflection in a workplace connects with experiential learning, which is defined as "the process whereby knowledge is created through the transformation of experience and knowledge results from the combination of grasping and transforming experience" (Kolb, 1984, p. 41).

Since the 1990s, competencies have become code words for the human resources and strategic management practices of recruiting, selecting, placing, leading, and training employees and evaluating employee performance. Competency-based assessment and feedback has become a predominant workplace reality, which is commonly used as an organizational development tool for the learner (McCarthy & Garavan, 2001). A competency-based assessment tool popularized in the 1980s, mostly as an executive development tool that gained currency in the 1990s, is the multi-rater or 360-degree feedback process (McCarthy & Garavan, 2001). The fundamental premise is that data gathered from multiple perspectives are more comprehensive and objective than data gathered from only one source (Dyer, 2001).

Many organizations use some form of the 360-feedback assessment process (Nowack, 1993), and it is implemented in a variety of ways. Ratings from self and others, however, constitute the core of the 360-degree feedback process (Tornow & London, 1998). Self-ratings are the first step to development for the feedback recipient. The value lies in the diversity of information it provides to the feedback recipient and how it is interpreted. It can be perceived as a positive self-development platform, in stark contrast to traditional top-downward evaluation process. Under ideal circumstances, it is used as an assessment for personal development rather than evaluation (Tornow & London, 1998). Widespread in many organizations around the world (Brutus et al., 2006), this process is reportedly used by 90% of Fortune 500 companies in the United States (Carruthers, 2003). The popularity of this practice has stimulated much research enthusiasm in the academic field (Dai, De Meuse, & Peterson, 2010).

Incentivizing Competency-Based Learning

Institutional accountability, articulation and student transfer issues, and workplace market alignment have become critical drivers that can provide the impetus for institutions to shift to competency-based models (A. Voorhees, 2001). Increasingly, accreditation requirements challenge faculty to look ahead to anticipate emerging skills or a change in the emphasis on certain skills that could impact the preparedness of engineers and technology graduates for employability in the knowledge-intensive workplace. Competencies provide students with a clear map and the navigational tools needed to move expeditiously toward their goals (R. Voorhees, 2001). The advantage of competency-based learning (CBL) is that competencies are transparent; that is, all participants in the learning process understand the learning goals and outcomes. Competency expectations have increased significantly across all sectors of the economy, and the abilities employers expect new college graduates to demonstrate the first day on the job have been ratcheted up to an "über level" (Hanneman & Gardner, 2010).

Purpose of the Study

Specifically, the primary purpose of this study was to measure student professional development utilizing an industry-based, 360-degree competency assessment process. An additional goal was the development of a framework for

CBL and assessment that can be used in other higher education settings.

The Foundation

Competency-Based Approach to Accreditation

The chosen Midwestern university's unique approach to accreditation requirements was to address them through development of workplace competencies (Brumm, Mickelson, et al., 2006). Identification of key industry employer needs drove this rationale: "employers of the graduates of our program are increasingly focusing on workplace competencies in their hiring practices, and student development of competencies is, therefore, critical to career success after graduation" (Brumm, Mickelson, et al., 2006, p. 1163). Through collaboration with Development Dimensions International, Inc. (DDI), a global provider of competency-based performance management tools and services, 14 unique workplace competencies were developed (http://learn.ae.iastate.edu/Competencydefinitions.pdf). These competencies were mapped directly to outcomes of degree programs. Seven, which were regularly mentioned by employers, were identified as "core" competencies. Each competency was defined clearly, concisely, and independently. Specific to each definition, a set of observable and measurable key actions was developed. By closely tying competencies with performance-based assessment of those competencies, a bridge is built between traditional measures of student achievement and competency-based approaches (R. Voorhees, 2001).

Course Connectivity

Competency-based models rely on both the judgment of those external to the learning process and on measurable assessment (R. Voorhees, 2001). A conceptual model of learning based on competencies does not work solely at the level of skill, abilities, and knowledge but seeks to formulate curriculum and assessment at the competency level; this embodies integration of skills, abilities, and knowledge needed to become part of the disciplinary community of practice (Jones, 2001). Competencies have a stronger impact on student learning when they are linked to and embedded within specific courses and across the curriculum (DDI, 2004).

A lean/cellular manufacturing course for senior-level undergraduate students provided the opportunity to design a CBL experience. Based on the instructor's industry background, professional development based on competency assessment was considered critical to prepare students for success in the workplace environment. The intent of the course design was to provide students the opportunity to "step through the looking glass" and understand the roles competencies and competency assessment play in professional/career development. In this pursuit, all coursework and activities developed were focused on competency development. This chosen Midwestern university's Industrial Technology assessment plan already contained competency-based learning tools that easily integrated into the course: 14 workplace competencies and a competency assessment format. Based on previous stakeholder assessment feedback, all 14 workplace competencies would not be utilized for the 360-degree process. Thus, a review of the course "core" competency frequency, coupled with the instructor's 360-degree assessment industry experience, was used to identify the top five course competencies: (a) analysis and judgment, (b) communication, (c) initiative, (d) continuous learning, and (e) teamwork. These top five competencies were the basis for the implementation of the 360-degree assessment process, and they are shown in Table 1.

Method

Twenty-six students enrolled in a lean/cellular manufacturing course in the Industrial Technology program at the Midwestern university that participated in this study. The top five competencies were used for initial and final assessments, of both self and peers, during the semester. Key actions associated with each competency were assessed utilizing the department's Likert-scale format. These assessment ratings were based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost never, 2 = seldom, 3 = sometimes, 4 = often, and 5 = always or almost always.

The top five competencies, along with the assessment process, were introduced to students the first day of the course. The students completed an online initial competency self-assessment the first week of class focused on these five competencies. During the second week of class, industry teams were formed, and industry mentors were assigned for the semester's lean manufacturing project. During the first five weeks, students experienced in-class simulations and other instructional activities involving lean tool applications, including: 5S, value stream mapping, A3, standard work, JIT, and jidoka

Table 1. "Top Five" Course Competencies and Definitions

Competency	Definitions
Analysis and Judgment	Identifying and understanding issues, problems, and opportunities; developing the relevant criteria and comparing data from different sources to draw conclusions: using effective approaches for choosing courses of action or developing appropriate solutions; taking actions that are consistent with available facts, constraints, and probably consequences.
Communication	Clearly conveying information and ideas through a variety of media to individuals or groups in a manner that engages the audience and helps them understand and retain the message.
Initiative	Taking prompt action to accomplish objectives; taking action to achieve goals beyond what is required; being proactive.
Continuous Learning	Actively identifying new areas for learning; regularly creating and taking advantage of learning opportunities: using newly gained knowledge and skill on the job, and learning through applications.
Teamwork	Effectively participating as a member of a team to move the team toward completion of goals.

Table 2. Course Competencies and Key Actions Assessed

Competency	Key Actions	
Analysis & Judgment	KA1	Identifies issues, problems and opportunities.
	KA2	Gathers information.
	KA3	Interprets information.
	KA4	Generates alternatives.
	KA5	Chooses appropriate action.
	KA6	Commits to action.
	KA7	Involves others.
	KA8	Values diversity.
Communication	KA1	Organizes the communication.
	KA2	Maintains audience attention.
	KA3	Adjusts to audience.
	KA4	Ensures understanding.
	KA5	Adheres to accepted conventions.
	KA6	Comprehends communication from others.
Initiative	KA1	Goes above and beyond.
	KA2	Responds quickly.
	KA3	Takes independent action.
Continuous Learning	KA1	Targets learning needs.
	KA2	Seeks learning activities.
	KA3	Maximizes learning.
	KA4	Applies knowledge or skill.
	KA5	Takes risks in learning.
Teamwork	KA1	Facilitates goal accomplishment.
	KA2	Informs others on team.
	KA3	Involves others.
	KA4	Models commitment.
Engineering/Technical Knowledge	KA1	Knowledge of mathematics.
	KA2	Knowledge of science.
	KA3	Knowledge of experimental analysis.
	KA4	Knowledge of current engineering/technology tools*
	KA5	Knowledge of technology.

(Pascal, 2007). At mid-term, student teams presented their lean project progress/status overview, and completed an "initial" online peer/team member assessment. The instructor provided confidential peer feedback to each student the following week. The student lean project teams spent the next five weeks predominantly out of the classroom working on-site with their industry mentors. During the 14th week, final self- and peer-competency assessments were completed. The instructor provided confidential results for peer assessments the following week.

Results

All initial and final competency assessments were analyzed with SPSS 19 software using paired sample t-testing. The t-test is the optimal data analysis method used to compare the means of paired samples and is recommended for small sample sizes (N < 30). The self- and peer-competency assessments were assigned to all students. One student didn't complete the initial, and another didn't complete the final self-assessment. These were not included in the data analysis (N = 24). Definitions of the top five competencies are shown in Table 1. The competencies' key action items, shown in Table 2, were assessed, and an average value was reported.

Self-Assessment

The average results for key action items within each of the top five competencies, based on the initial and final self-assessments are shown in Figure 1. Additionally, Table 3 provides specific paired t-Test self-assessment results for the key actions (KA). Significant differences ($p < .05$) are indicated with an asterisk (*). Overall, an increase in final over the initial assessed average value was found in at least one key action (KA) item (*) for each of the five top competencies. These measured average increases serve as an indicator of self-assessed professional development.

Self- vs. Peer Assessments

A comparison of the results for the key actions between all self- and peer assessments is shown in Figures 2 and 3, respectively. In the initial assessment, significant differences (*) were detected in specific key action items in two of the five competencies (analysis and judgment, and teamwork), between self and peer results. In

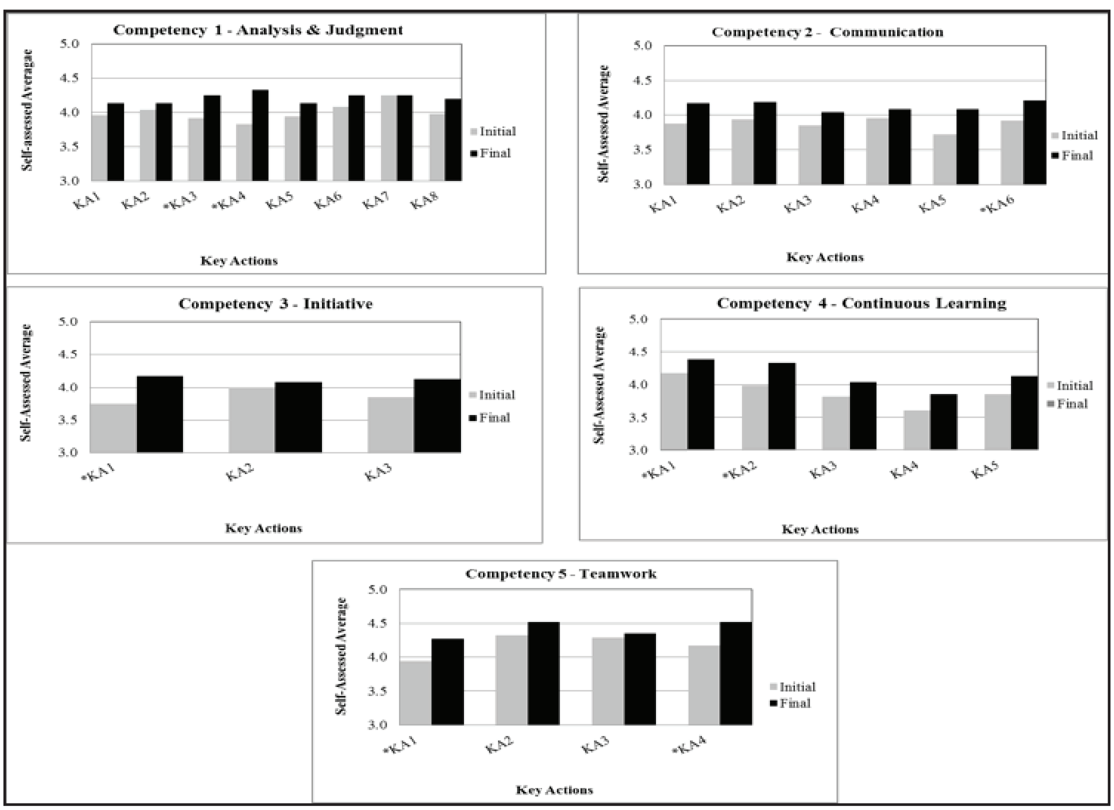

Figure 1. Self-assessed average for five workplace competencies' key actions. (N = 24). *p < .05, two-tailed. Self-assessment average results. The Likert scale used was based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost never, 2 = seldom, 3 = sometimes, 4 = often, and 5 = always or almost always.

Table 3. Paired Significance Means t-Test for Competency Self-Assessments (*N*=24)

Competency	Key Action	Assess	M	SD	t	df	r	p
1. Analysis & Judgment								
Chooses appropriate action	KA1	initial	3.96	0.464	-1.446	23	0.235	0.162
		final	4.13	0.448				
Gathers information	KA2	initial	4.04	0.550	-0.526	23	-0.018	0.604
		final	4.13	0.537				
Generates alternatives	KA3	initial	3.92	0.584	-2.326	23	0.306	0.029*
		final	4.25	0.608				
Identifies issues, problems, and opportunities	KA4	initial	3.83	0.581	-3.464	23	0.370	0.002*
		final	4.33	0.670				
Interprets information	KA5	initial	3.94	0.648	-0.901	23	-0.308	0.377
		final	4.13	0.612				
Commits to action	KA6	initial	4.08	0.654	-0.089	23	-0.055	0.382
		final	4.25	0.608				
Involves others	KA7	initial	4.25	0.590	0.000	23	0.539	1.000
		final	4.25	0.752				
Valuing diversity	KA8	initial	3.98	0.651	-1.394	23	0.377	0.177
		final	4.20	0.592				
2. Communication								
Adheres to accepted conventions	KA1	initial	3.88	0.680	-1.664	23	-0.066	0.110
		final	4.17	0.482				
Adjusts to the audience	KA2	initial	3.94	0.631	-1.813	23	0.241	0.830
		final	4.19	0.404				
Comprehends communication from others	KA3	initial	3.85	0.744	-1.013	23	0.110	0.322
		final	4.04	0.606				
Ensures understanding	KA4	initial	3.96	0.624	-0.647	23	-0.098	0.524
		final	4.08	0.654				
Maintains audience attention	KA5	initial	3.73	0.659	-1.764	23	-0.094	0.910
		final	4.08	0.670				
Organizes the Communication	KA6	initial	3.92	0.637	-2.299	23	0.351	0.031*
		final	4.21	0.404				
3. Initiative								
Goes above and beyond	KA1	initial	3.75	0.626	-2.908	23	0.399	0.008*
		final	4.17	0.654				
Responds quickly	KA2	initial	4.00	0.643	-0.558	23	0.309	0.583
		final	4.08	0.602				
Takes independent action	KA3	initial	3.85	0.651	-1.313	23	-0.245	0.202
		final	4.13	0.630				
4. Continuous Learning								
Applies knowledge or skill	KA1	initial	4.17	0.602	-1.479	23	0.292	0.015*
		final	4.38	0.557				
Maximizes learning	KA2	initial	3.98	0.699	-2.132	23	0.260	0.044*
		final	4.33	0.637				
Seeks learning activities	KA3	initial	3.81	0.548	-1.326	23	0.051	0.198
		final	4.04	0.674				
Takes risks in learning	KA4	initial	3.60	0.737	-1.297	23	0.118	0.207
		final	3.85	0.683				
Targets learning needs	KA5	initial	3.85	0.744	-1.556	23	0.119	0.133
		final	4.13	0.540				
5. Teamwork								
Facilitates goal accomplishment	KA1	initial	3.94	0.558	-2.563	23	0.316	0.017*
		final	4.27	0.531				
Informs others on team	KA2	initial	4.33	0.545	-1.334	23	0.252	0.195
		final	4.52	0.580				
Involves others	KA3	initial	4.29	0.550	-0.514	23	0.501	0.612
		final	4.35	0.634				
Models commitment	KA4	initial	4.17	0.637	-2.717	23	0.517	0.012*
		final	4.52	0.651				

Note.*p < .05, two-tailed. Assessed average results for each key action (KA) related to the top 5 course competencies. The Likert scaled used for assessment was based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost never, 2 = seldom, 3 = sometimes, 4 = often, and 5 = always or almost always.

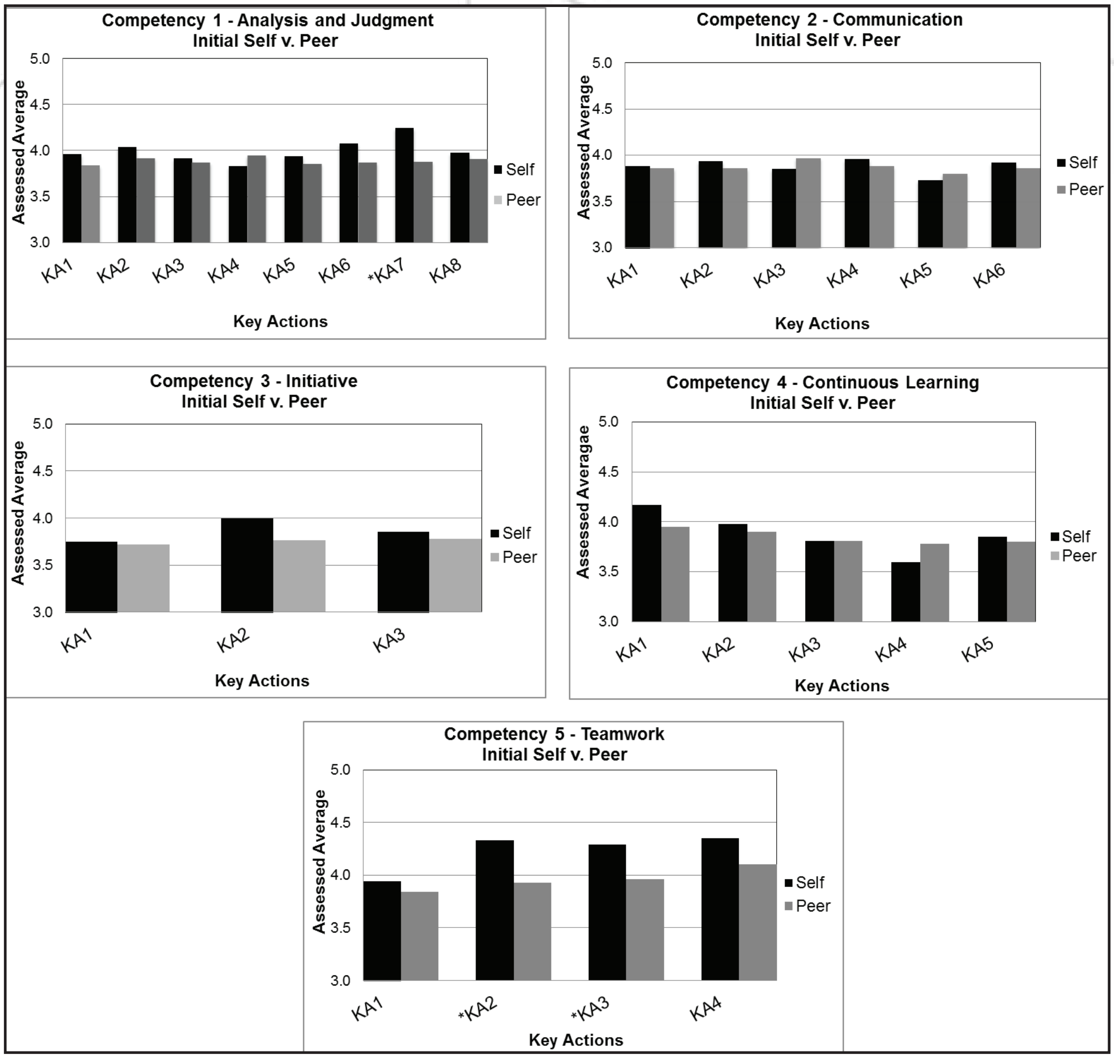

Figure 2. Initial self- vs. peer-assessed average ranking for key actions. (*N* = 24). *p < .05. The Likert scale used was based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost never, 2 = seldom, 4 = often, and 5 = always or almost always.

all cases, the self-assessed average results were higher than peer-assessed average results. In the final assessment results, significant differences in specific key action item averages were also found for two of the five competencies (initial and teamwork). Once again, self-assessed average values were higher than peer-assessed average values. Results indicate that for both the initial and final assessments, KA2 in the teamwork competency was the significant difference commonality. Additionally, Table 4 provides specific paired t-Test self-assessment results for the key actions (KA). Significant differences ($p < .05$) are indicated with an asterisk (*).

Peer Assessments

The average results for key action items contained within each of the top five competencies for the initial and final peer assessments are shown in Figure 4, with significant differences ($p < .05$) indicated with an asterisk (*). Overall, in four of the five competencies, significant differences (*) in the average assessed value were found in at least one key action item. These key action items experienced an increased average value in the final average assessed value over the initial. Additionally, Table 5. provides specific paired t-Test peer assessment results. As a peer assessment/student aggregate, this measured increase serves as an indication of professional growth over the semester.

Findings

A 360-degree assessment process was implemented into an undergraduate course utilizing the department's competency assessment format. Key action items associated with the top five course competencies were assessed. The self-assessment results showed higher final average assessed values in at least one key action item for each of the five competencies. No commonalities in the key action items between the initial and final

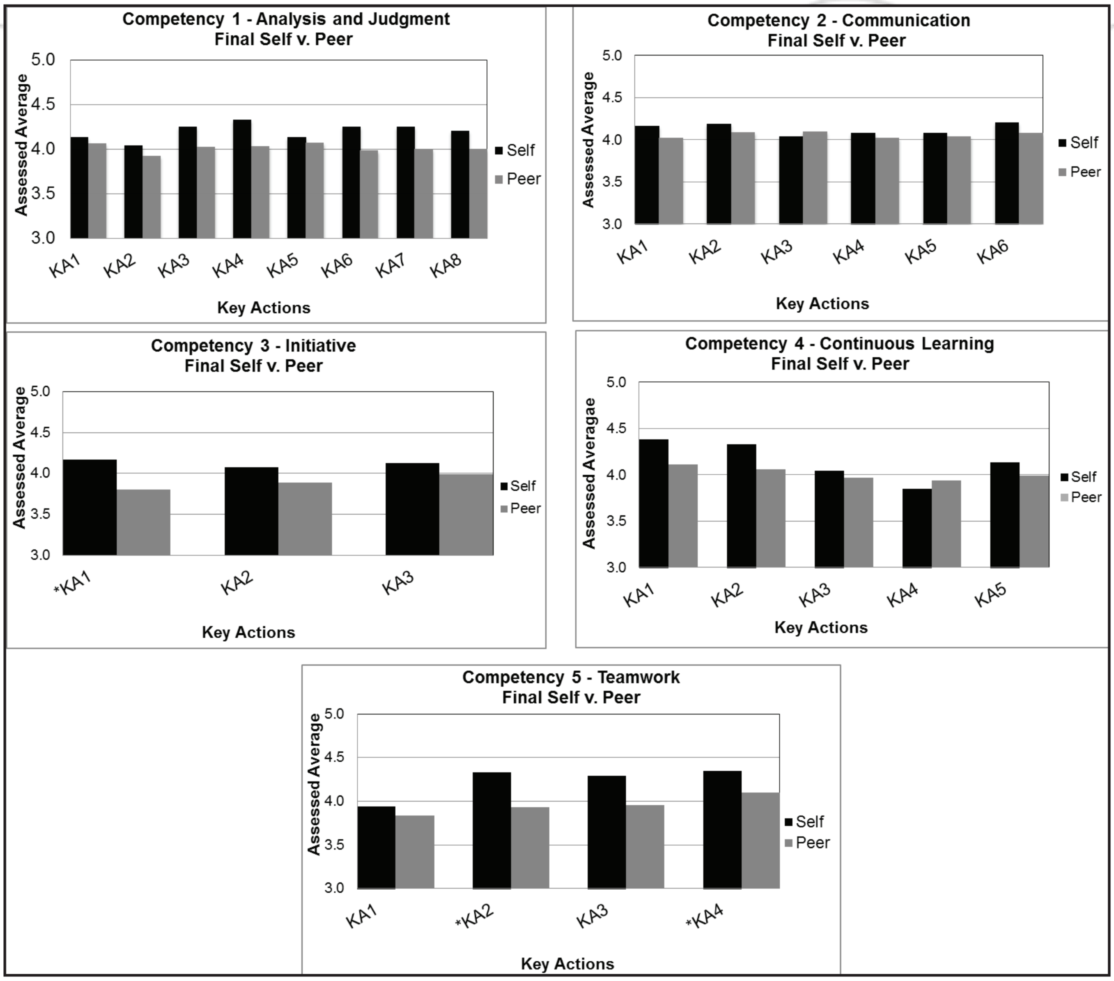

Figure 3. Final self- vs. peer-assessed average rankings for key actions (*N* = 24) *p < .05. The Likert scale used was based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost never, 2 = seldom, 4 = often, and 5 = always or almost always.

self-assessment results were observed. The measured increases in key action final average results indicated self-perceived professional gains achieved (Figure 1). The comparison of self- v. peer-assessment results showed two commonalities:

1. Higher average values were all detected in the self-assessments, and

2. Teamwork competency: KA2 showed higher self-assessed values in both the initial and final assessments (Figures 2 and 3).

The overall peer-assessment results showed higher average final results in at least one key action item for each of the five course competencies (Figure 4).

Discussion and Conclusions

The results are indicative of the complex task of comparing self-perception to others, which involves social information processing and interpersonal insight (London, 1994). Psychological mechanisms related to how we operate in social environments may become impediments to accurate self-assessment. In this study, significant differences detected in comparing self-assessments v. peer assessments showed self-assessments with higher average values. As Tornow (1993) found, self-assessments are, on average, higher than others, including peers. Although peer ratings often tend to be far lower than self-ratings, they are fast becoming one of the most valued sources of appraisal as opposed to the usual supervisor ratings (McCarthy & Garavan, 2001). According to Jones and Bearley (1996), this is a direct consequence of an organization's increased focus on self-managed work teams and flatter structures. Peer feedback provides insight into how one behaves in team situations; it also explains the influencing behaviors that serve to gain commitments when no direct authority can be

Table 4. Paired Significance Means t-Test for Competency Self vs. Peer Assessments (*N*=24)

Competency	Key Actions	Assess	Mself	Mpeer	t	df	r	p
1. Analysis & Judgment								
Chooses appropriate action	KA1	initial	3.96	3.84	1.633	23	0.534	0.116
		final	4.13	4.06	0.677		-0.243	0.505
Gathers information	KA2	initial	4.04	3.92	1.136	23	-0.054	0.268
		final	4.13	4.06	0.748		0.052	0.462
Generates alternatives	KA3	initial	3.92	3.87	0.655	23	0.208	0.519
		final	4.25	4.02	1.875		0.040	0.074
Identifies issues, problems,	KA4	initial	3.83	3.95	-0.703	23	0.091	0.489
and opportunities		final	4.33	4.03	1.976		0.033	0.060
Interprets information	KA5	initial	3.94	3.86	0.628	23	0.160	0.536
		final	4.13	4.07	0.542		0.254	0.593
Commits to action	KA6	initial	4.08	3.87	1.724	23	0.188	0.098
		final	4.25	3.98	1.777		-0.055	0.089
Involves others	KA7	initial	4.25	3.88	3.037	23	0.018	0.006*
		final	4.25	4.00	1.474		-0.027	0.154
Valuing diversity	KA8	initial	3.98	3.91	0.601	23	0.238	0.554
		final	4.20	4.00	1.595		0.354	0.125
2. Communication								
Adheres to accepted conventions	KA1	initial	3.88	3.86	0.256	23	-0.043	0.800
		final	4.17	4.02	1.245		0.044	0.226
Adjusts to the audience	KA2	initial	3.94	3.86	0.465	23	-0.262	0.647
		final	4.19	4.09	1.169		0.166	0.254
Comprehends communication	KA3	initial	3.85	3.97	-0.593	23	0.064	0.559
from others		final	4.04	4.10	-0.134		0.064	0.895
Ensures understanding	KA4	initial	3.96	3.88	0.685	23	0.056	0.500
		final	4.08	4.02	0.571		0.038	0.573
Maintains audience attention	KA5	initial	3.73	3.80	-0.363	23	-0.105	0.720
		final	4.08	4.04	0.447		-0.030	0.659
Organizes the Communication	KA6	initial	3.92	3.86	0.602	23	0.028	0.553
		final	4.21	4.08	1.479		0.262	0.153
3. Initiative								
Goes above and beyond	KA1	initial	3.75	3.72	0.392	23	0.211	0.699
		final	4.17	3.80	2.295		0.097	0.031*
Responds quickly	KA2	initial	4.00	3.76	1.747	23	-0.129	0.094
		final	4.08	3.89	1.425		0.143	0.168
Takes independent action	KA3	initial	3.85	3.78	0.617	23	-0.174	0.544
		final	4.13	3.99	0.984		0.074	0.335
4. Continuous Learning								
Applies knowledge or skill	KA1	initial	4.17	3.95	1.736	23	-0.121	0.096
		final	4.38	4.11	1.684		-0.245	0.106
Maximizes learning	KA2	initial	3.98	3.90	0.517	23	-0.243	0.610
		final	4.33	4.06	1.559		-0.396	0.133
Seeks learning activities	KA3	initial	3.81	3.81	0.194	23	-0.089	0.848
		final	4.04	3.97	0.536		0.023	0.597
Takes risks in learning	KA4	initial	3.60	3.78	-0.999	23	-0.099	0.328
		final	3.85	3.94	-0.336		-0.036	0.740
Targets learning needs	KA5	initial	3.85	3.80	0.391	23	-0.420	0.699
		final	4.13	3.99	1.215		0.116	0.237
5.Teamwork								
Facilitates goal accomplishment	KA1	initial	3.94	3.84	0.761	23	-0.283	0.454
		final	4.27	4.07	1.521		-0.185	0.142
Informs others on team	KA2	initial	4.33	3.93	3.328	23	-0.047	0.003*
		final	4.52	4.07	3.040		0.066	0.006*
Involves others	KA3	initial	4.29	3.96	2.876	23	0.131	0.009*
		final	4.35	4.10	1.985		0.283	0.059
Models commitment	KA4	initial	4.17	4.23	-0.071	23	-0.264	0.944
		final	4.52	4.01	3.112		0.091	0.005*

Note.*p < .05, two-tailed. Assessed average results for each key action (KA) related to the top 5 course competencies. The Likert scaled used for assessment was based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost never, 2 = seldom, 3 = sometimes, 4 = often, and 5 = always or almost always.

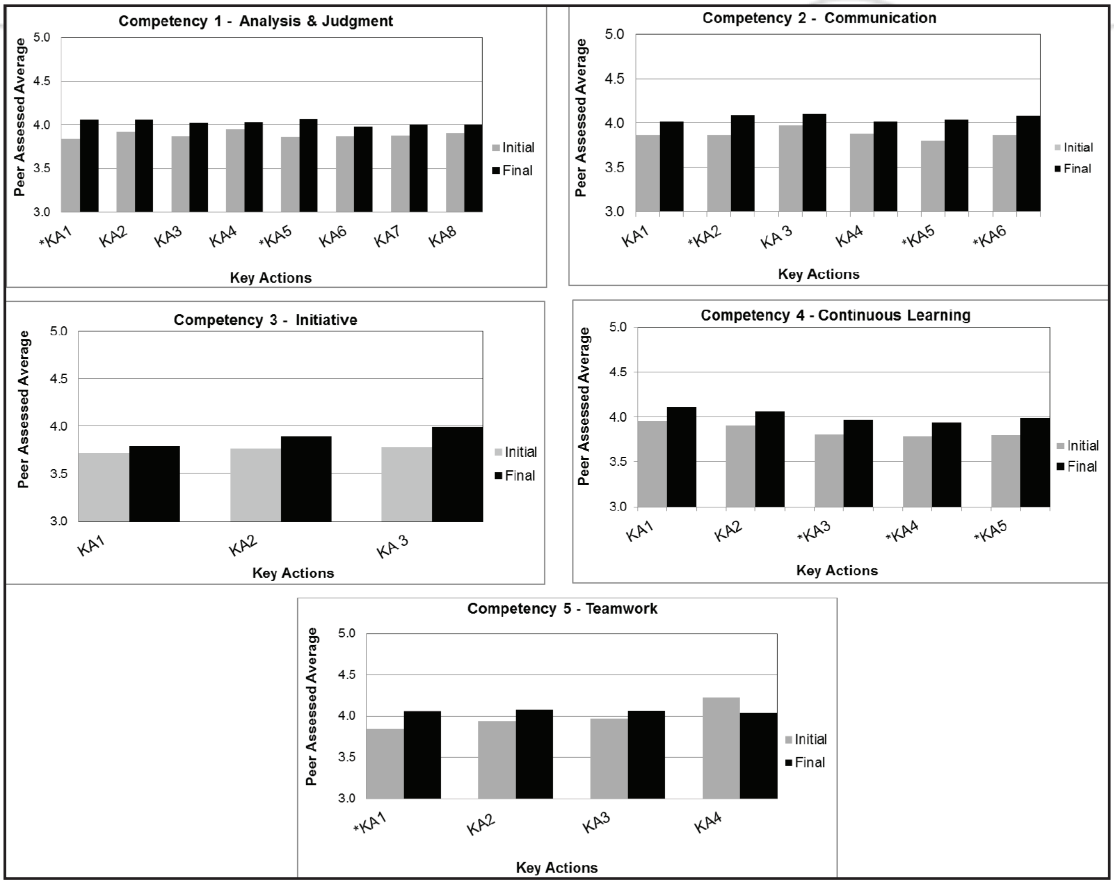

Figure 4. Peer-assessed average ranking for key actions (N = 24) *p < .05. Assessed average results for each key action (KA) related to the top 5 course competencies. The Likert scale used for assessment was based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost never, 2 = seldom, 3 = sometimes, 4 = often, and 5 = always or almost always.

exercised (Lepsinger & Lucia, 1997). Classroom research has demonstrated reasonable agreement between self- and peer ratings (McGourty, Dominick, Besterfield-Sacre, Shuman, & Wolfe, 2000), and correlations ranging from 0.12 to 0.39 (Reilly, 1996) have been reported. Correlations results found in this study ranged from –0.429 to 0.534 for the initial self- vs. peer assessments and from –0.394 to 0.354 for the final assessments. Researchers have suggested that low agreement may be due to real behavioral or skill differences in the target student as perceived by sources with different perspectives such as fellow students (Tornow, 1993).

This case study was limited to the assessment of the top five workplace competencies determined for one course, one semester (16 weeks), and small sample size (N = 24). A great deal of research has been directed at the relationship between individual characteristics and rating tendencies; research has focused on characteristics of the raters, the ratee, or both. These characteristics were not the central focus of this study. Additionally, self- and peer evaluations are not entirely free of bias, also not addressed in this study. Rather, the focus was to determine if competency assessment could be implemented into the classroom to measure and detect evidence of perceived student professional development.

The value of competency assessment as a measure both in this study and in industry is that it provides input that can be utilized into professional self-development efforts. This study provided a framework for competency-based learning and assessment that can be utilized in a higher education environment. Despite its limitations, the implications for future research are evident. More studies are needed to collect and analyze data regarding competency-based learning and the use of multisource/360-degree assessments to measure student professional development in an educational setting. It gives us an inkling of the possibilities and impact that future studies can provide, not only to improve our approach to student assessment, but also in curricular improvement efforts that better prepare students for their professional endeavors.

Table 5. Paired Significance Means t-Test for Competency Peer Assessments (*N*=24)

Competency	Key Actions	Assess	M	SD	t	df	r	p
1. Analysis & Judgment								
Chooses appropriate action	KA1	initial	3.84	0.371	-2.652	23	0.509	0.014*
		final	4.06	0.461				
Gathers information	KA2	initial	3.92	0.288	-1.562	23	0.467	0.131
		final	4.06	0.514				
Generates alternatives	KA3	initial	3.87	0.327	-1.059	23	0.259	0.300
		final	4.02	0.503				
Identifies issues, problems, and opportunities	KA4	initial	3.95	0.377	-1.028	23	0.664	0.314
		final	4.03	0.535				
Interprets information	KA5	initial	3.86	0.338	-2.452	23	0.571	0.022*
		final	4.07	0.521				
Commits to action	KA6	initial	3.87	0.336	-0.998	23	0.307	0.328
		final	3.98	0.584				
Involves others	KA7	initial	3.88	0.330	-1.319	23	0.553	0.199
		final	4.00	0.581				
Valuing diversity	KA8	initial	3.91	0.394	-0.780	23	0.412	0.433
		final	4.00	0.577				
2. Communication								
Adheres to accepted conventions	KA1	initial	3.86	0.459	-1.652	23	0.468	0.111
		final	4.02	0.494				
Adjusts to the audience	KA2	initial	3.86	0.373	-3.037	23	0.617	0.006*
		final	4.09	0.048				
Comprehends communication from others	KA3	initial	3.97	0.329	-1.528	23	0.578	0.139
		final	4.10	0.524				
Ensures understanding	KA4	initial	3.88	0.303	-1.810	23	0.542	0.082
		final	4.02	0.457				
Maintains audience attention	KA5	initial	3.80	0.337	-2.732	23	0.45	0.011*
		final	4.04	0.465				
Organizes the Communication	KA6	initial	3.86	0.350	-2.706	23	0.62	0.012*
		final	4.08	0.528				
3. Initiative								
Goes above and beyond	KA1	initial	3.72	0.364	-0.606	23	0.424	0.550
		final	3.80	0.692				
Responds quickly	KA2	initial	3.76	0.429	-0.943	23	0.266	0.355
		final	3.89	0.670				
Takes independent action	KA3	initial	3.78	0.374	-1.728	23	0.156	0.096
		final	3.99	0.534				
4. Continuous Learning								
Applies knowledge or skill	KA1	initial	3.95	0.183	-1.614	23	0.104	0.119
		final	4.11	0.513				
Maximizes learning	KA2	initial	3.90	0.309	-1.700	23	0.438	0.101
		final	4.06	0.538				
Seeks learning activities	KA3	initial	3.81	0.395	-2.064	23	0.614	0.049*
		final	3.97	0.048				
Takes risks in learning	KA4	initial	3.78	0.273	-2.101	23	0.53	0.046*
		final	3.94	0.439				
Targets learning needs	KA5	initial	3.80	0.260	-2.080	23	0.406	0.048*
		final	3.99	0.504				
5.Teamwork								
Facilitates goal accomplishment	KA1	initial	3.84	0.415	-2.830	23	0.536	0.009*
		final	4.07	0.463				
Informs others on team	KA2	initial	3.93	0.035	-1.311	23	0.428	0.202
		final	4.07	0.584				
Involves others	KA3	initial	3.96	0.033	-1.227	23	0.335	0.213
		final	4.10	0.592				
Models commitment	KA4	initial	4.23	0.487	1.874	23	0.482	0.073
		final	4.01	0.665				

Note.*p < .05, two-tailed. Assessed average results for each key action (KA) related to the top 5 course competencies. The Likert scaled used for assessment was based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost never, 2 = seldom, 3 = sometimes, 4 = often, and 5 = always or almost always.

Dr. Jacqulyn A. Baughman is a Lecturer in the Department of Ag & Biosystems Engineering, and Director of Graduate Education for the Biorenewable Resources and Technology Graduate Program at Iowa State University, Ames. She is a member of the Alpha Xi chapter of Epsilon Pi Tau.

Dr. Thomas J. Brumm is an Associate Professor in the Department of Ag & Biosystems Engineering, Director of Assessment for the College of Engineering, and Professor-in-Charge of Engineering-LAS Online Learning at Iowa State University, Ames. He is a member of the Alpha Xi chapter of Epsilon Pi Tau.

Dr. Steven K. Mickelson is the Charles R. & Jane F. Olsen Professor of Engineering and Chair of the Ag & Biosystems Engineering Department at Iowa State University, Ames.

References

Brumm, T., Mickelson, S., Steward, B., & Kaleita, A. (2006). Competency-based outcomes assessment for agricultural engineering programs. *International Journal of Engineering Education, 22*(6), 1163–1172.

Brutus, S., Derayeh, M., Fletcher, C., Bailey, C., Velazques, P., Shi, K., Labath, V. (2006). Internationalization of multi-source feedback systems: A six country exploratory analysis of 360-degreee feedback. *International Journal of Human Resource Management, 18*, 1888–1906.

Carruthers, F. (2003). Nothing but the truth. *Australian Financial Review,* 78.

Chickering, A., & Reisser, L. (1993). *Education and identity* (2nd ed.). San Francisco: Jossey-Bass.

Dai, G., De Meuse, K., & Peterson, C. (2010). Impact of multi-source feedback on leadership competency development: A longitudinal field study. *Journal of Managerial Issues 22*, 197–219.

Development Dimensions International [DDI]. (2004). Retrieved on January 30, 2012, from www.ddiworld.com

Dyer, K. (2001). The power of 360-degree feedback. *Educational Leadership, 5*, 35–38.

Ennis, M. (2008). Competency models: *A review of the literature and the role of the employment and training administration* (ETA). Pilots and Demonstration Team, Division of Research and Evaluation, Office of Policy Development and Research Employment and Training Administration: U.S. Department of Labor.

Evans, N. J., Forney, D. S., & Guido-DiBrito, F. (1998). *Student development in college: Theory, research, and practice.* San Francisco: Jossey-Bass.

Ewell, P. (1984). *The self-regarding institution; information for excellence.* National Center for Higher Education Management Systems. Boulder, Colorado, pp. 45–57.

Gardner, S. K. (2009). Student development theory: A primer. *ASHE Higher Education Report,* 34(6), 15–28.

Hanneman, L., & Gardner, P. (2010). *CERI research brief 1-2010: Under the economic turmoil a skills gap simmers.* Collegiate Employment Research Institute, Michigan State University. Retrieved August 1, 2011, from http://www.ceri.msu.edu

Hayward, L., & Blackmer, B. (2007). *A 360-degree assessment model for integrating technical and professional skills to facilitate successful workplace transition.* Retrieved from http://www.naceweb.org/foundation/done/360degree/?referal=

Hayward, L., Noonan, A., & Shain, D. (1999). Qualitative case study of physical therapist students' attitudes, motivations, and affective behaviors. *JAH, 28*(3), 155–164.

Jones, E. (2001). Working in partnership with faculty to transform undergraduate curricula. *New Directions for Institutional Research, (110),* 15–27.

Jones, J., & Bearley, W. (1996). *360-degree feedback: Strategies, tactics and techniques for developing leaders.* Minneapolis: Lakewood Publications.

Kolb, D. (1984). *Experiential learning: Experience as the source of learning and development.* Englewood Cliffs, NJ: Prentice-Hall.

Lepsinger, R., & Lucia, A. (1997). *The art and science of 360-degree feedback.* San Francisco: Jossey-Bass

London, M. (1994). Interpersonal insight into organizations: Cognitive models for human resource development. *Human Resource Management Review, 4*, 311–332.

McCarthy, A., & Garavan, T. (2001). 360 [degrees] feedback process: Performance, improvement and employee career development. *Journal of European Industrial Training, 25(1),* 5–32. Retrieved August 1, 2011, from ABI/INFORM Global. (Document ID: 115923735).

McEwen, M. K. (2005). The nature and uses of theory. In M. E. Wilson & L. Wolf-Wendel (Eds.), *ASHE reader on college student development theory* (pp. 5–24). Boston: Pearson Custom Publishing.

McGourty, J., Dominick, P., Besterfield-Sacre, M., Shuman, L., & Wolfe, H. (2000). Improving student learning through the use of multisource assessment and feedback. 30th ASEE/IEEE Frontiers in Education Conference. October 18–21, 2000, Kansas City, MO.

National Center for Education Statistics [NCES]. (2002). *Defining and assessing learning: Exploring competency-based initiatives,* NCES 2002-159. The Council of the National Postsecondary Education Cooperative Working Group on Competency-Based Initiatives. Washington, DC: U.S. Department of Education.

Nowack, K. M. (1993). 360-degree feedback: The whole story. *Training & Development, 47(1)*, 69. Retrieved September 5, 2011, from ABI/INFORM Global. (Document ID: 818982).

Pascal, D. (2007). *Lean production simplified: A plain-language guide to the world's most powerful production system* (2nd ed.). Boca Raton, FL: CRC Press, Taylor & Francis Group.

Reilly, R. (1996). *Team feedback.* Presented at the 11th Annual Conf. Society for Industrial and Organizational Psychology, San Diego, CA, 1996.

Rodgers, R. F. (1990). Recent theories and research underlying student development. In D. Creamer & Associates (Eds.), *College student development: Theory and practice for the 1990s* (pp. 27–79). Alexandria, VA: American College Personnel Association.

Tornow, W. (1993). Perspective or reality? Is multi-perspective measurement a means or an end? *Human Resources Management, 32*, 221–229.

Tornow, W., & London, M. (1998). *Maximizing the value of 360-degree feedback: A process for successful individual and organizational development.* San Francisco: Jossey-Bass.

Voorhees, A. (2001). Creating and implementing competency learning models. *New Directions for Institutional Research, 2001*(110), 83–95.

Voorhees, R. (2001). Competency-based learning models: A necessary future. *New Directions for Institutional Research, 2001*(110), 5–13.

The 2011 Paul T. Hiser Exemplary Publication Award Recipient

Luke J. Steinke and Alvin R. Putnam

"Mentoring Teachers in Technology Education: Analyzing the Need"

The Board of Editors of The Journal of Technology Studies and the Board of Directors are pleased to announce the recipient of the Paul T. Hiser Exemplary Publication Award for Volume XXXVII, 2011.

The Board of Directors established this award for deserving scholars. In recognition for his exemplary service to the profession and to the honorary as a Trustee and Director, the award bears Dr. Hiser's name. It is given to the author or authors of articles judged to be the best of those published each year in this journal.

Selection Process

Each member of the Editorial Board recommends the manuscript that he or she considers the best of those reviewed during the year. The board nominates articles based on their evaluation against specific criteria. A majority vote of the editors is required for the award to be made. The honor society's Board of Directors renders final approval of the process and the award.

Criteria

1. The subject matter of the manuscript must be clearly in the domain of one or more of the professions in technology.

2. The article should be exemplary in one or more of the following ways:
   - Ground-breaking philosophical thought.
   - Historical consequence in that it contains significant lessons for the present and the future.
   - Innovative research methodology and design.
   - Trends or issues that currently influence the field or are likely to affect it.
   - Unique yet probable solutions to current or future problems.

A $300 award recognizes the recipient(s) for the year and is presented during an Epsilon Pi Tau program at an annual professional association conference.

GUIDELINES FOR

The Journal of Technology Studies

A refereed publication of Epsilon Pi Tau the international honor society for professions in technology.

The Journal of Technology Studies (JOTS) is the flagship, peer-reviewed journal of Epsilon Pi Tau, an international honor society for technology professions. Two print issues per year are mailed to all members of the society as well as to academic and general libraries around the globe. These printed issues, plus additional issues available only in electronic format as well as past issues, are available free on-line at scholar.lib.vt.edu/ejournals/jots.

SUBJECT FOCUS

The JOTS welcomes *original* manuscripts from scholars worldwide focused on the depth and breadth of technology as practiced and understood past, present, and future. Epsilon Pi Tau, as perhaps the most comprehensive honor society among technology professions, seeks to provide upto-date and insightful information to its increasingly diverse membership as well as the broader public. Authors need not be members of the society in order to submit manuscripts for consideration. Contributions from both academics and practitioners are equally welcome.

A general guide to the breadth of topics of potential interest to our readers can be gained by consideration of the 17 subclasses within "Technology" of the classification scheme of the Library of Congress, USA <lcweb.loc.gov.catdir/cpso/lcco/lcco_t.pdf>. This includes engineering and allied disciplines, informatics in its many manifestations, industrial technology, and education in and about technology. Authors are strongly urged to peruse this list as they consider developing articles for journal consideration. In addition, JOTS is interested in manuscripts that provide:

- brief biographical portraits of leaders in technology that highlight the difference these individuals made in distinct fields of technology or its wider appreciation within society,
- thoughtful reflections about technology practice,
- insights about personal transitions in technology from formal education to the work environment or vice versa,
- history, philosophy, sociology, economics, and anthropology of technology,
- technology within society and its relationship to other disciplines,
- technology policy at local, national, and international levels,
- comparative studies of technology development, implementation, and/or education,
- industrial research and development,
- new and emerging technologies and technology's role in shaping the future.

Within this immense diversity of technology, its applications and import, authors must communicate clearly, concisely, informatively, and only semi-technically to readers from a diverse set of backgrounds. Authors may assume some technical background on the part of the reader but not in-depth knowledge of the particular technology that is the focus of the article. Highly technical articles on any field of technology are not within the purview of the journal. Articles whose subject focus has been extensively explored in prior issues of the journal are only of potential interest if they: 1) open up entirely new vistas on the topic, 2) provide significant new information or data that overturns or modifies prior conceptions, or 3) engage substantially one or more previously published articles in a debate that is likely to interest and inform readers. Syntheses of developments within a given field of technology are welcome as are metanalyses of research regarding a particular technology, its applications, or the process of technical education and/or skill acquisition. Research studies should employ methodological procedures appropriate to the problem being addressed and must evince suitable design, execution, analysis, and conclusions. Surveys, for example, that exhibit any or all of the following characteristics are of no interest to the journal: 1) insufficient awareness of prior research on this topic, 2) insufficient sample size, 3) improper survey design, 4) inappropriate survey administration, 5) high mortality, 6) inadequate statistical analysis, and/or 7) conclusions not supported by either the data or the research design employed. The journal is neutral in regards to qualitative, quantitative, or mixed method approaches to research but insists on research quality.

GUIDELINES FOR
The Journal of Technology Studies
(Continued)

GUIDELINES FOR SUBMISSION

Articles must conform to the most current edition of the Publication Manual of the American Psychological Association. All articles must be original, represent work of the named authors, not be under consideration elsewhere, and not be published elsewhere in English or any other language. Electronic submissions in either rich-text format or Microsoft Word formats are encouraged, although submission of three printed copies and a diskette containing the article are also permissible. E-mail submissions should be sent to the editor, Dr. Dominick Fazarro, at jots@bgsu.edu. Paper submissions should be mailed to:

Editor, Journal of Technology Studies
Epsilon Pi Tau, Technology Building
Bowling Green State University
Bowling Green, Ohio 43403-0296

Manuscripts should be no more that 25 pages, double spaced, including references. Typescript should be *Times New Roman* or a close approximation of font and 12 point. Only manuscripts in the English language will be accepted and they should conform to American usage. Figures, tables, photographs, and artwork must be of good quality and conform to APA form and style.

REVIEW PROCESS

Articles deemed worthy by the editor for consideration by Authors who submit an article that does not merit review by the editorial board are informed within approximately two weeks of receipt of the article so that they may explore other publishing venues. A rejection may be based solely on the content focus of the article and not its intrinsic merit, particularly where the topic has been extensively explored in prior JOTS articles. Articles that exhibit extensive problems in expression, grammar, and spelling are summarily rejected. Authors of articles that have been peer-reviewed are informed within about three months from the date of submission of the article. Anonymous comments of reviewers are provided to authors that are invited to submit a revised article for either publication or a second round of review. The editor does not automatically provide reviewer comments to authors whose articles have been rejected via the peer review process but makes a judgement based on whether the feedback might prove beneficial to the authors as they pursue other publishing opportunities.

PUBLICATION

Authors whose articles have been accepted, will have their final products published in the on-line version of the journal. Selected articles from the on-line edition of the journal may also appear in two print issues that are issued per calendar year. All authors will receive a pdf version of their published article and co-retain rights to that article along with Epsilon Pi Tau. The editor will supply when requested information about an accepted article that has not yet appeared in print for faculty undergoing tenure review.