# 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.

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.

**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),

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.

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.

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

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<br>• Visual and Information Literacy<br>• Cultural Literacy and Global Awareness |
| Inventive Thinking – Intellectual Capital | • Adaptability/Managing Complexity and Self Direction<br>• Curiosity, Creativity, and Risk-taking<br>• Higher-Order Thinking and Sound Reasoning |
| Interactive Communication – Social and Personal Skills | • Teaming and Collaboration<br>• Personal and Social Responsibility<br>• Interactive Communication |
| Quality, State-of-the-Art Results | • Prioritizing, Planning, and Managing<br>• Effective Use of Real-World Tools<br>• 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.

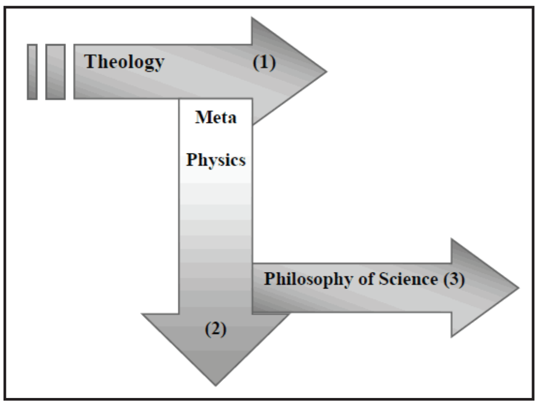


**Figure 1. Changing the direction of thought mainstream (as flow) according to Comte's three mentally conceived stages.**

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.

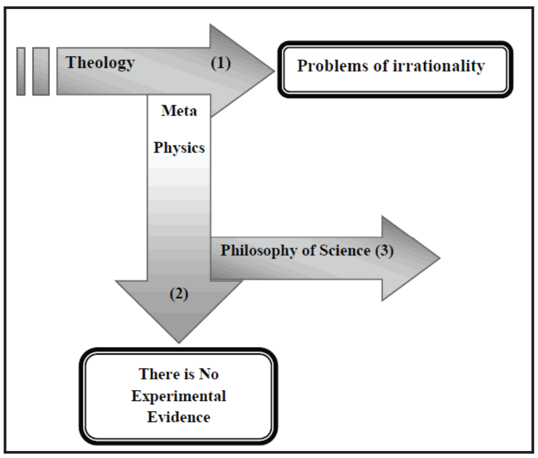


**Figure 2. Flow of thought and effect of obstructions.**

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.

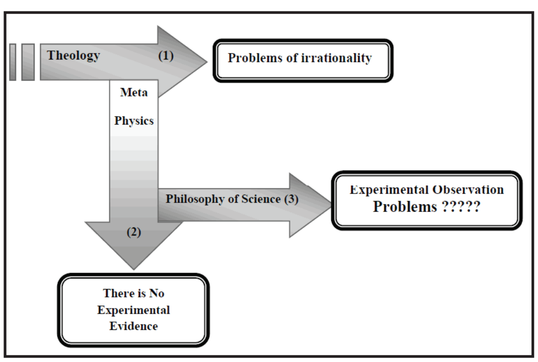


**Figure 3. The problems that change thought.**

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),

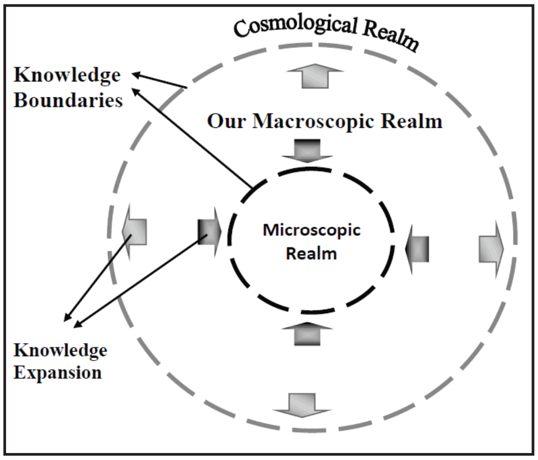


**Figure 4. The boundaries of scientific knowledge.**

which is clearly observed in developed countries. Figures 5 & 6 show the funding of 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.

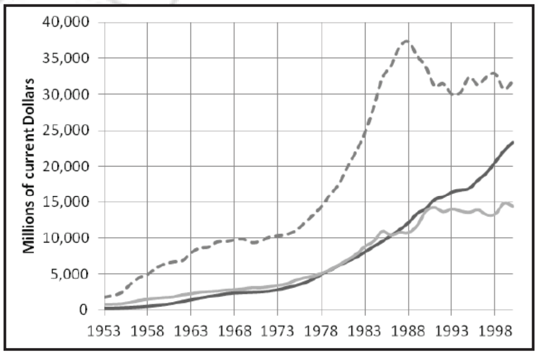


**Figure 5. U.S. federal government spending development for the basic, applied and development research (1953-2000) (Science and Engineering, Indicators 2002).**

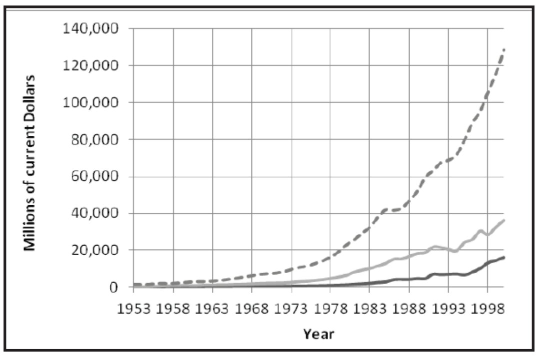


**Figure 6. The U.S. industry spending development for basic, applied and development research (1953-2000) (Science and Engineering Indicators, 2002).**

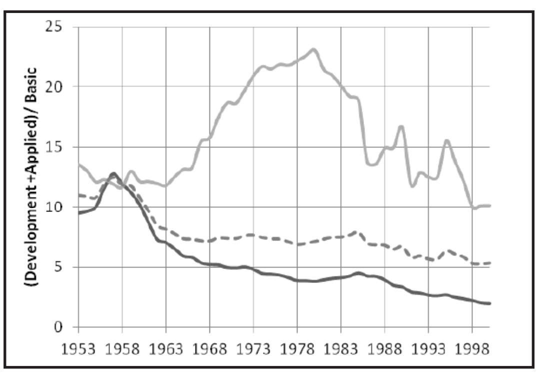


**Figure 7. The ratio of U.S. spending on R&D to spending on basic science for both federal government and industry sectors (1953-2000).**

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

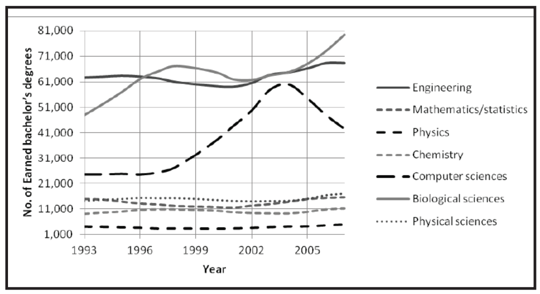


**Figure 8. The number of the earned bachelor's degrees in USA for different field at period 1993-2007 (Science and Engineering Indicators, 2010).**

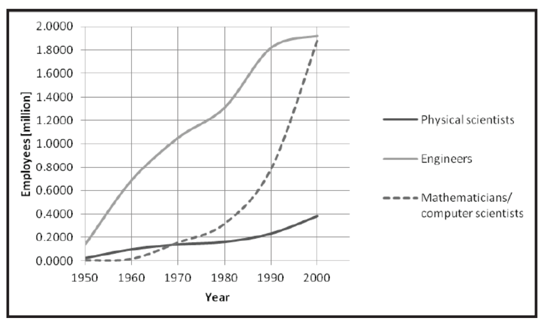


**Figure 9. Employees in science and technology in the USA 1950-2000 (Science and Engineering Indicators, 2010).**

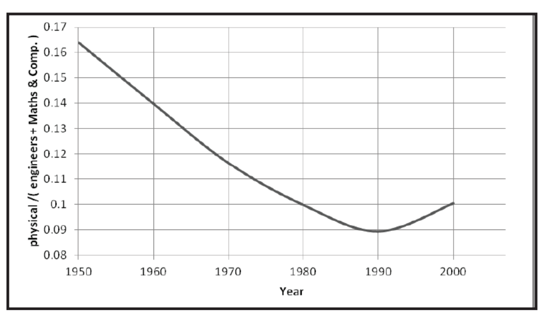


**Figure 10. The ratio of physical scientists to engineers, mathematicians and computer scientists.**

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.

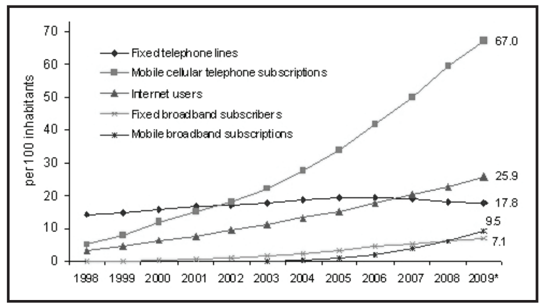


**Figure 11. Global ICT developments, 1998 – 2009 (ITU World Telecommunication/ ICT Indicators database, 2009).**

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).

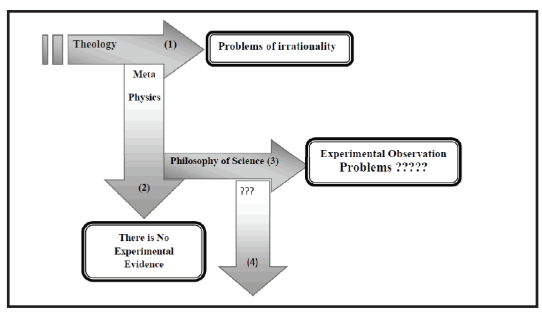


**Figure 12. The possible fourth stage.**

***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.

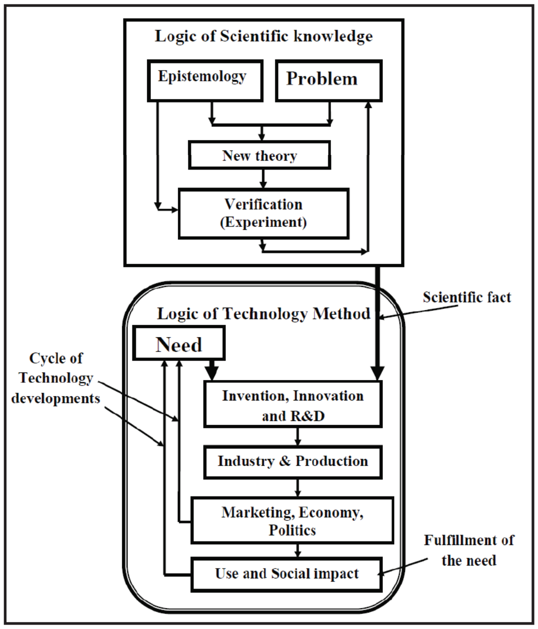


**Figure 13. The logic of scientific knowledge and technological methodology.**

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

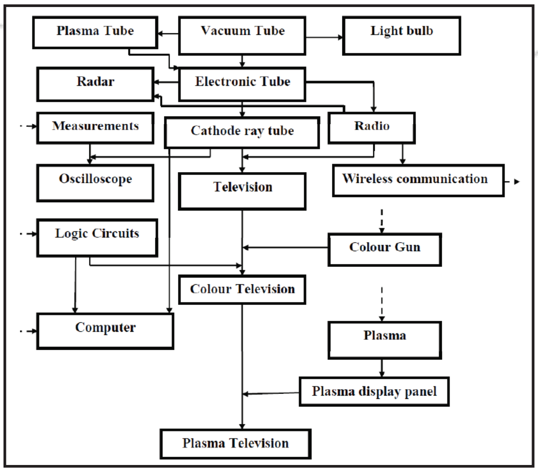


**Figure 14. A branch of the vacuum tube family that includes the evolution of the television (Sanduk, 2003).**

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.

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.

**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 |

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.* Chicago: 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

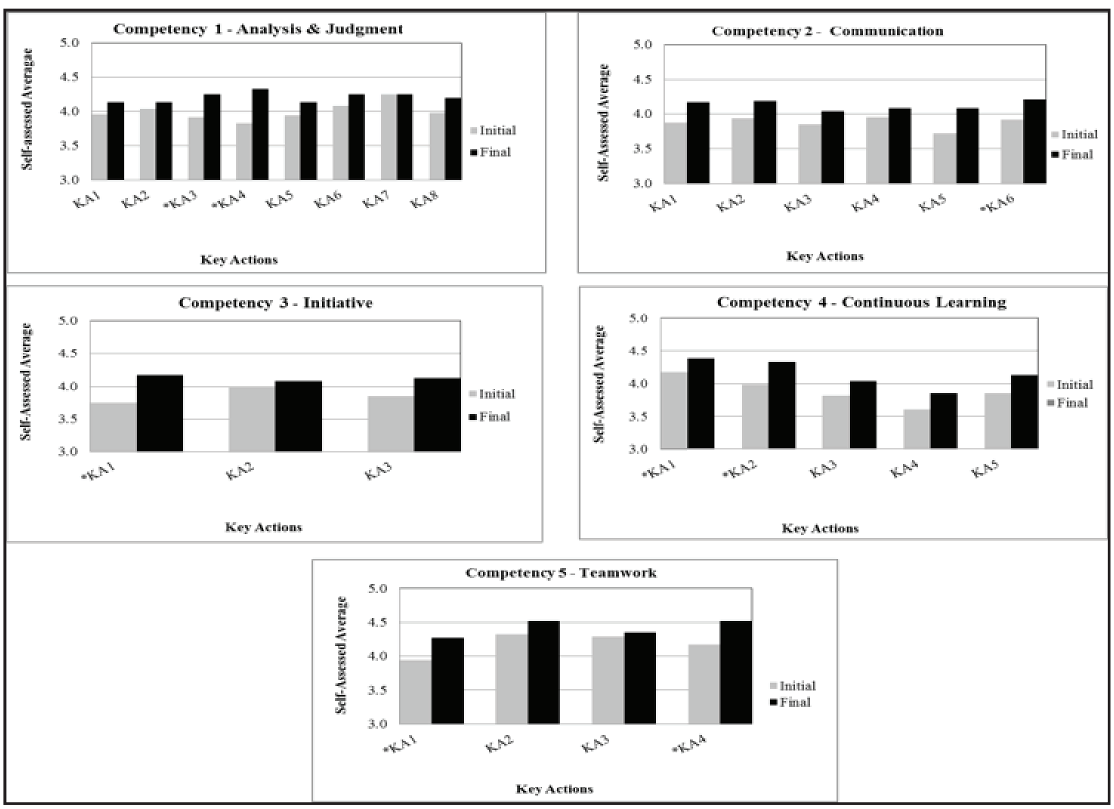


**Figure 1. Self-assessed average for five workplace competencies' key actions. (N = 24). *p < .05, two-tailed. Self-assessment average results. The Likert scale used was based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost never, 2 = seldom, 3 = sometimes, 4 = 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.

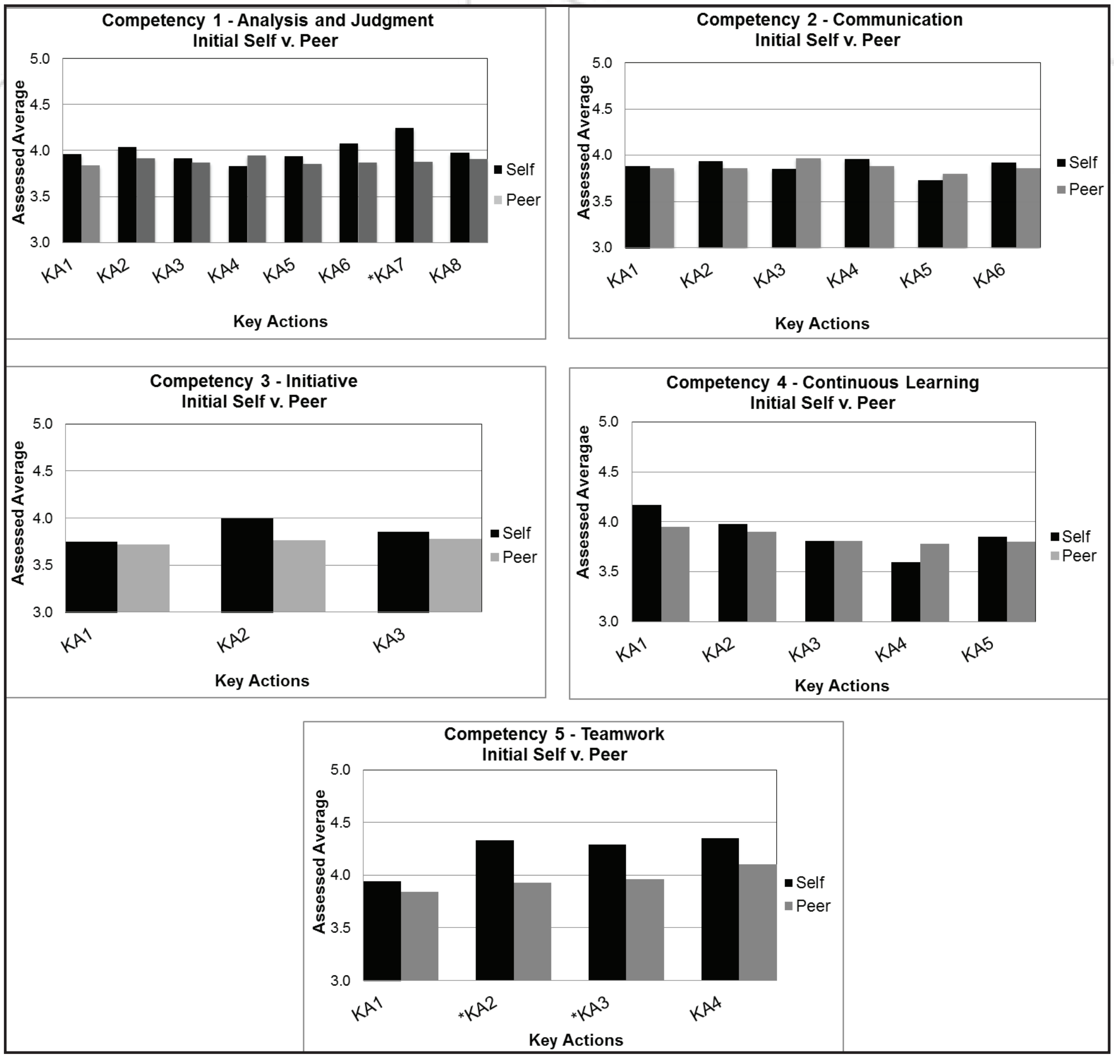


**Figure 2. Initial self- vs. peer-assessed average ranking for key actions. (*N* = 24). *p < .05. The Likert scale used was based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost never, 2 = seldom, 4 = often, and 5 = always or almost always.**

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

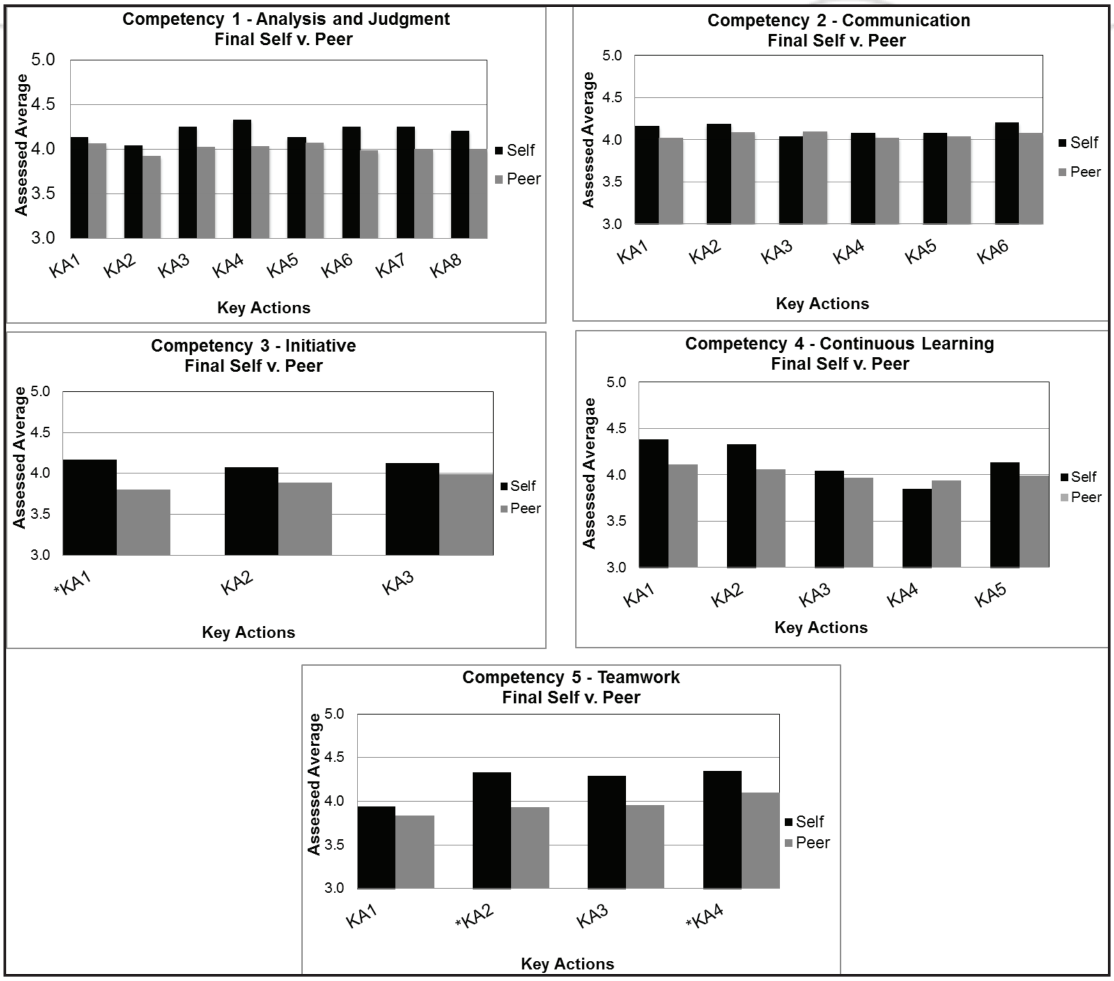


**Figure 3. Final self- vs. peer-assessed average rankings for key actions ($N$ = 24) *p < .05. The Likert scale used was based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost never, 2 = seldom, 4 = often, and 5 = always or almost always.**

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.

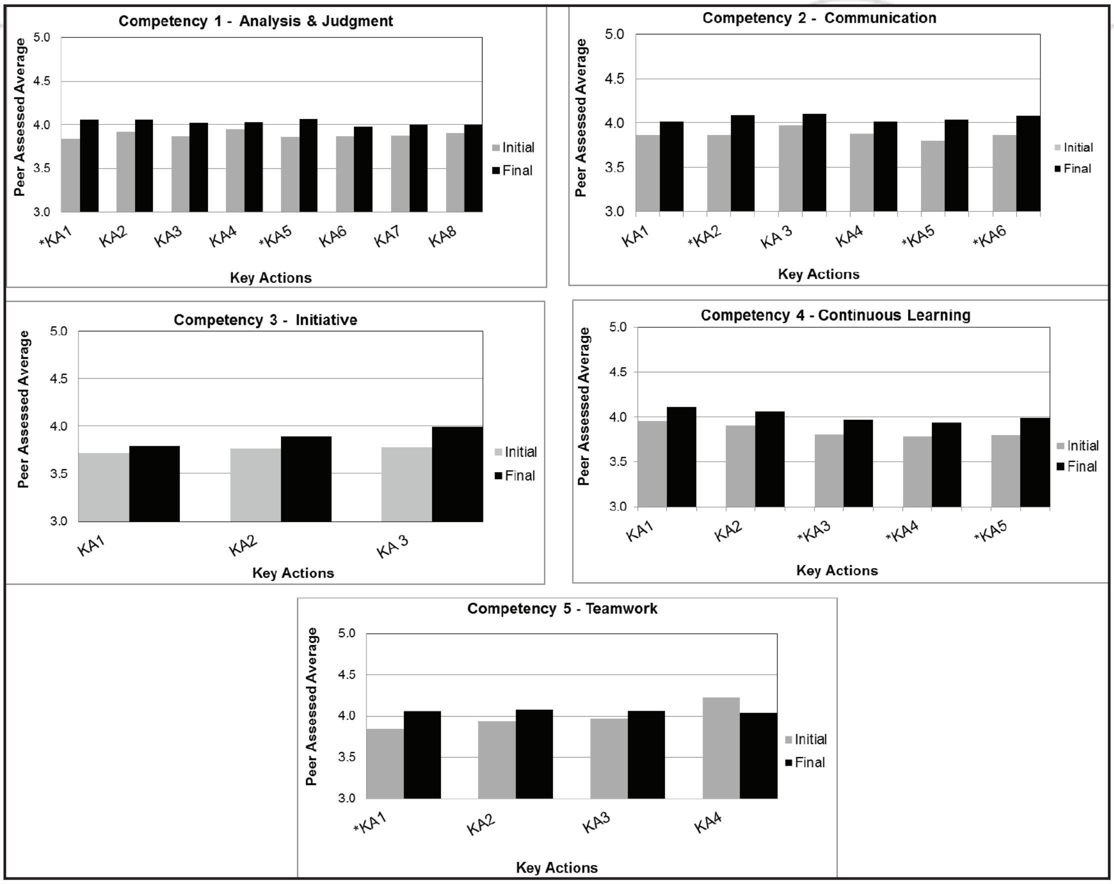


**Figure 4. Peer-assessed average ranking for key actions (*N* = 24) *p < .05. Assessed average results for each key action (KA) related to the top 5 course competencies. The Likert scale used for assessment was based on how often a key action was performed, ranging from 1 to 5 with 1 = never or almost 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.