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Todd R. Kelley
Purdue University

Robert C. Wicklein
University of Georgia

Recommended Citation
Kelley, T. R., & Wicklein, R.C. (2009) Teacher challenges to implement engineering design in secondary technology education (Third in a 3-part series). Journal of Industrial Teacher Education 46(3), 34-50.

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Teacher Challenges to Implement Engineering Design in Secondary Technology Education
(Third article in 3-part series)

Todd R. Kelley, Ph.D.
Purdue University

Robert C. Wicklein, Ed.D.
University of Georgia

Abstract

This descriptive study examined the current status of technology education teacher practices with respect to engineering design. This article is the third article in a three-part series presenting the results of this study. The first article in the series titled *Examination of Engineering Design Curriculum Content* highlighted the research findings regarding engineering design curriculum content delivered by technology education teachers. The second article in the series titled *Examination of Assessment Practices for Engineering Design Projects in Secondary Technology Education* reported technology education teachers' assessment practices when implementing engineering design projects in the classroom. The sample for this study was drawn from the current International Technology Education Association (ITEA) membership database. This article will present the research findings that identified challenges faced by technology educators when seeking to implement engineering design.

Todd R. Kelley, Ph.D., is an Assistant Professor in the Department of Industrial Technology at Purdue University. He can be reached at trkelley@purdue.edu.
Robert C. Wicklein, Ed.D., is a Professor at the University of Georgia. He can be reached at wickone@uga.edu.

Introduction

There are a growing number of leaders in technology education who are encouraging the implementation of a new focus for technology education: a focus on infusing engineering design concepts into technology education (Daugherty, 2005; Hill, 2006; Wicklein, 2006). Simultaneously, curriculum programs such as *Project Lead The Way*, *Engineering by Design*, and *Project ProBase* have provided new curriculum options for technology education teachers to infuse engineering concepts into technology classrooms (Rogers, 2005; Dearing & Daugherty, 2004). Some states have taken great strides to assist the field of technology education move towards an engineering focused curriculum. Administrators within the Departments of Education in Georgia have been working to assist technology education teachers to move their curricular efforts to an engineering design focus (Kelley, Denson, & Wicklein, 2007). Educators in the state of Massachusetts have even adopted curriculum standards that place specific emphasis on the infusion of engineering concepts into the technology education curriculum (Massachusetts Department of Education, 2001). In 2004, the State of Maryland also adopted new standards in technology education to include engineering concepts, and similar efforts have taken place in the State of New Jersey (Ross & Bayles, 2007). Although these are trends that suggest the field of technology education is on the move, the field's history of resisting change may be a cause for concern to the question of, is real change taking place in actual teacher practice (Clark, 1989; Sanders, 2001)? In addition, questions arise about what hurdles, barriers, and challenges are preventing successful curriculum changes from taking place related to an engineering design focus for technology education? It is an appropriate

time to investigate what challenges are facing technology education teachers as they seek to infuse engineering design into technology education. This article is derived from results from a larger status study related to engineering design in technology education. The research question that will guide this study is; what selected challenges and barriers are identified by secondary technology educators when teaching engineering design in technology education?

Related Literature

Identifying barriers standing in the way of successfully infusing engineering design and pre-engineering into K-12 classrooms has been investigated by a number of researchers (Shields, 2007; Yasar, Baker, Robinson-Kurpius, Krause, & Roberts, 2006). Shields (2007) investigated barriers to implementing Project Lead The Way (PLTW) programs as perceived by Indiana high school principals and identified the *cost of implementing PLTW* as a significant obstacle (M 3.6 SD 0.91 on a 5-Likert scale).

Yasar, et al. (2006) developed an instrument to assess K-12 teachers' perceptions of engineers, and familiarity with teaching Design, Engineering, and Technology (DET). They conducted research with 98 K-12 teachers in the State of Arizona and identified ten items as perceived barriers to teaching DET. *Time* and *administrative support* were identified as barriers to infuse DET into the curriculum. Furthermore, participants who were identified as being unfamiliar with DET also indicated that they lacked confidence in their abilities to teach DET. Others have also identified that K-12 teachers lack confidence in their abilities to teach design and engineering and as a result shy away from implementing engineering concept into the classroom (Brophy, Klein, Portsmore, & Rogers, 2008; Creighton, 2002).

Focus groups participating in a leadership workshop on K-12 Engineering Outreach held by the American Society of Engineering Education (ASEE) in 2004 with over 150 educators in attendance identified the lack of state standards as a major constraint to promoting engineering education at the K-12 level (Douglas, Iversen, & Kalyandurg, 2004). This observation of a lack of standards was stated even though the States of Maryland, Massachusetts, and New Jersey have developed engineering content standards, providing state support for teaching engineering concepts in K-12 classrooms (Ross & Bayles, 2007).

Recently several program initiatives have been created to provide professional development experiences for technology education teachers to assist in infusing engineering design concepts into the classroom (Burghardt &Hacker, 2007; Burke & Meade, 2007; DeMiranda, Troxell, Siller, & Iversen, 2008; Ross & Bayles, 2007). As a result of these professional development experiences, a number of challenges facing technology teachers as they seek to make these curricular changes have been identified. One such project that aids a teacher in the area of engineering education is INSPIRES Curriculum (INcrease Student Participation, Interest and Recruitment in Engineering and Science). Funded by the National Science Foundation (NSF) this project is designed to provide professional development and engineering focused curriculum for technology education teachers (Ross & Bayles, 2007). During the INSPIRES professional development workshops, technology education teachers (N=17) indicated that although the teachers acknowledge the importance of making connections between science and engineering (63% strongly agree), only 31% of the technology teachers surveyed indicated they were strongly prepared to do so. Only 25% of the technology teachers attending the INSPIRES workshop indicated that they provide instruction to make connection

between science and engineering. Ross and Bayles (2007) indicated they discovered through follow-up classroom observations that technology education teachers tended to minimize the mathematical and simulation portions of the INSPIRES curriculum, instead, rushing students to build projects. Furthermore, the researchers rarely witnessed technology education teachers explicitly discussing the science and mathematical concepts embedded in the design challenges with students. Sanders (2008) indicated that technology education teachers are rarely known to explicitly identify science or mathematical concepts as student learning outcomes embedded within a lesson or learning activity.

Gattie & Wicklein (2007) investigated perceptions of ITEA members towards curricular value of the infusion of engineering design. This research sought to identify the instructional needs of high school technology educators regarding engineering design instruction. Over 90% of the in-service teachers indicated that engineering design was an appropriate focus for their instructional program. However, the teachers in this sample also indicated some strong needs to properly infuse engineering design in technology education. Several notable needs identified were that 93% of the teachers indicated the need to learn how to integrate the appropriate levels of mathematics and science into instructional content and 87% indicated the need to develop additional analytical (mathematics) skills (Gattie & Wicklein , 2007). The instrument included a total of thirteen identified instructional needs to teach engineering design.

Although this review of literature reveals research studies that have identified challenges, barriers, and constraints to the infusion of engineering concepts or engineering design into the classroom, most of these studies have not focused on secondary technology educators. For example, Shields (2007) surveyed Indiana principals; likewise, Yasar, Baker, Robinson-

Kurpius, Krause, and Roberts (2006) surveyed Arizona K-12 educators. Clearly, a study is necessary to identify the most common challenges facing technology education teachers across the nation as they seek to infuse engineering design into secondary classrooms and to further extend the results of the Gattie and Wicklein's (2007) study.

Methodology

This descriptive study drew a full sample of high school technology teachers from the current International Technology Education Association (ITEA) membership list. The sample consisted of all high school technology teachers regardless of whether they indicated they were teaching engineering design in their classroom. The identified population of this study consisted of a total of (N) 1043 high school technology education teachers in the ITEA membership database as of September 11, 2007. Using the Krejcie and Morgan (1970) method to locate sample size for a given population, the required sample size was set at 285 (Gay & Airasin, 2000). The original research design for this study called for an increase of the initial mailing of the survey by 48.1 percent, the average success rate of an initial mailing (Gall, Gall, & Borg, 2007). However, close communication with ITEA personnel revealed that ITEA survey mailings typically yield a 20-25% rate of return (Price, personal communication). The researcher determined that a full sample mailing to all ITEA high school members was necessary to achieve the desired sample of 285.

An invitation message was sent electronically through e-mail to all ITEA members in the sample, explained specific instructions for completing the on-line questionnaire and directed participants to access a specific website to obtain and complete the survey questionnaire. The on-line questionnaire was developed using the guidelines and recommendations

outlined by Dillman, Tortora, and Bowker (1999). There was a request to return the survey on a specified date.

The researchers sent out the surveys to the entire sample group of 1043 high school teachers. After waiting three days past the specified date of return which was three weeks after the initial mailing, the researcher contacted non-respondents by sending a follow-up e-mail delivered letter containing the URL for the on-line survey link. This has been a proven method used by other researchers to achieve compliance from non-respondents (Gall et al., 2007).

Results

Teacher challenges were identified as barriers, problems, or issues that often occur for technology educators as they seek to make curriculum changes towards engineering design as a focus and could possibly impede their ability to successfully implement necessary changes. The teacher challenges section of the survey instrument asked participants to rate their level of experience with fourteen selected teacher challenges using a five point Likert-type scale (0 = Never, 1 = Rarely, 2 = Sometimes, 3 =Very Often, and 4 = Always). The fourteen selected teacher challenges were adapted from the Gattie and Wicklein (2007) study that also sought to identify the most commonly experienced of the identified challenges. The highest rated challenges were *integrating the appropriate levels of mathematics and science into instructional content* (mean of 2.49), *locating appropriate laboratory equipment to teach engineering design* (mean of 2.40), and *acquiring funding to purchase tools and equipment to teach engineering design* (mean of 2.31). Complete results of the teacher challenges for infusing engineering design into the technology education curriculum are presented in Table 1. Although these items yielded the highest mean scores, these results were below

the mid-point for a 5-point Likert scale with mean scores falling between 2 = Sometimes and 3 =Very Often. It can be concluded that these mean scores falling between 2 and 3 indicate that the average response for those who were participating in this study do experience these challenges, just not to a level 3 or *Very Often*. These results must be viewed in light of the fact that the results did not receive high mean scores (over means of 3). However, the higher mean scoring teacher challenge items in this study were similar in wording to teacher challenges that have been identified in other studies (Gattie & Wicklein, 2007; Ross & Bayles, 2007).

Table 1. Teacher Challenges Infusing Engineering

Teacher Challenges	*M*	SD
integrating the appropriate levels of mathematics and science into instructional content	2.49	0.88
locating and learning the appropriate levels of mathematics and science to teach engineering design	2.27	0.93
locating and learning knowledge of engineering fundamentals (statics, fluid mechanics, dynamics)	2.10	0.97
locating appropriate textbooks to teach engineering design	2.14	1.08
locating the appropriate laboratory equipment to teach engineering design	2.40	1.10
locating the appropriate laboratory layout and space to teach engineering design	2.18	1.17
acquiring funding to purchase tools and equipment to teach engineering design	2.31	1.23
acquiring funding to purchase materials to teach engineering design	2.25	1.21
networking with practicing engineers for consultation	2.04	1.15
obtaining support from mathematics and science faculty	1.96	1.08
obtaining support from school administration and school counselors	2.11	1.16
obtaining support to promote engineering design course by school administration	1.94	1.22
obtaining community support to implement engineering design courses	1.73	1.09
obtaining parent support to implement engineering design course	1.73	1.08

Design

The survey also contained one open-ended response question, allowing participants to identify any additional challenges they face that impedes them from infusing engineering design into technology education. These additional challenges were summarized and categorized into common themes. A careful review of these individually identified teacher challenges revealed that many respondents took the opportunity of the open-ended response question to further emphasize some of the previously identified challenges in the survey. The top challenges that were emphasized were (1) *lack of funding -acquiring funding to purchase tools and equipment to teach engineering design* (frequency of 14), and (2) *lack of support- from administration, guidance, mathematics and science faculty, community, or state education department* (frequency of 11); *a lack of clear and concise curriculum that is unrestricting and contains a proper blend of technical skills and knowledge* (frequency of 11); *a fear of enrollment loss of students due to lack of interest in engineering, low academic ability, and or motivation to take engineering courses* (frequency of 11). Other top teacher challenges that were identified by respondents was *a lack of time for professional development and teacher prep time* (frequency of 9). See Table 2 for a complete review of the additional teacher challenges identified by responders in the open-ended response question.

Table 2. Additional Teacher Challenges Identified by Participants (Open Ended Response)

Teacher Challenge	*f*
Money - lack of funds to purchase state of the art equipment, budget cuts, changes are costly	14
Curriculum Lack of clear and concise, unrestricting, appropriate blend of skill and knowledge	11
Support -lack of support from administration (3), guidance(1) mathematics and science teachers(1) community (2) State Education Dept (4)	11
Enrollment - fear of loss of students due to lack of interest, academic ability, motivation	11
Time - lack of time for professional development, teacher prep time, etc	9
Equipment and Software - lack of needed equipment, tools, and software	8
Student Schedule -lack of room in student schedule for electives due to graduation requirements	7
Teacher Knowledge - lack of teacher knowledge about engineering design content	3
Lab Space	3

Conclusions

The results of this study confirm discoveries found in subsequent research related to the engineering design curriculum content and assessment practices used by technology teachers to teach engineering design at the high school level. The teacher challenge results found respondents

indicating difficulties in locating and integrating appropriate levels of mathematics and science for engineering design. Technology teachers participating in this study indicated that *integrating the appropriate levels of mathematics and science to teach into instructional content* was often a challenge (mean 2.48; SD 0.88). The fourth highest mean score item was similar in context *locating and learning the appropriate level of mathematics and science to teach engineering design* (mean 2.27; SD 0.93). Other high mean scoring challenges were in *locating and acquiring appropriate tools and equipment to teach engineering design effectively*. The second highest identified challenge was *locating the appropriate laboratory equipment to teach engineering design* (mean 2.40; SD 1.10). The third highest mean scoring individual item was *acquiring funding to purchase tools and equipment to teach engineering design* (mean of 2.31; SD 1.23). Locating appropriate funding to acquire proper tools and equipment has often been identified as a top challenge for technology education teachers (Wicklein, 1993, 2005). It is also logical that technology teachers are identifying challenges in locating the appropriate laboratory equipment and acquiring the proper funds to purchase such equipment. Similarly, in a study of the status of engineering design in Georgia's technology education programs, Denson, Kelley, and Wicklein (2009) found that over 88.0 % of Georgia's technology education teachers identified a need to locate and acquire appropriate types of tools and test equipment to teach engineering design (mean of 3.20; SD 1.12). These results indicate that technology education teachers are often struggling to locate appropriate tools and equipment to teach engineering design in technology education. Moreover, there is little evidence in literature to suggest that anyone in the field of technology education has properly described the appropriate equipment to teach engineering design within technology education. The fact that

appropriate tools and testing equipment have not currently been identified spurred the Engineering and Technology Education Advisory Committee for Georgia Department of Education to recommend that a subcommittee be formed of technology education teachers, university professors, and school administrators in the state of Georgia to investigate and identify appropriate tools and test equipment that will assist technology teachers to teach engineering design in middle and high school technology education programs (Advisory Committee on Engineering and Technology Education in Georgia, 2008).

The participants in this study provide some indication why mathematics is not emphasized in technology education curriculum when they indicated that *integrating the appropriate levels of mathematics and science to teach into instructional content* (mean 2.48; SD 0.88) and *locating and learning the appropriate level of mathematics and science to teach engineering design* (mean 2.27; SD 0.93) were often challenges to successfully teach engineering design. These results indicate the need for developing additional professional development opportunities to assist technology educators to properly infuse engineering design into technology education curriculum. It is important to note that the debate is very much alive about what are the appropriate levels of mathematics and engineering science for teaching engineering design at the secondary level, more research is needed to determine what these appropriate levels would entail.

Implications for Professional Development

The results of this study provides an excellent opportunity for leaders in the state of Georgia, and any other state seeking to design professional development, to be informed about the teaching practice, assessment strategies,

and identified challenges of current technology education teachers seeking to implement engineering design curriculum. These results have identified teacher challenges faced when seeking to implement an engineering design focused technology education program. Information obtained from this research can help professional developers create workshops, curriculum, and support materials that will properly address teacher concerns and equip these educators with the necessary skills and knowledge to properly infuse engineering design into the classroom. Upon review of Table 1, the top three mean scores identified teacher challenges that can be addressed through teacher professional development and are necessary to overcome for technology education teachers to have the capacity to successfully infuse engineering design into the classroom. Professional development programs should be focused, consistent, and relevant to engineering design content while at the same time address these teacher challenges identified in this study.

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