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Editorial Board ■ Advisory Board ■ Review Board

Online Distribution

The online EDGJ is a reality as a result of support provided by **East Carolina University** and **Biwu Yang**, Research & Development, ECU Academic Outreach.

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Message from the Chair

Robert A. Chin, EDGD Chair
East Carolina University

The 72nd Midyear Conference: you should have been there! Go to https://commons.erau.edu/asee-edgd/conference72/ and scroll down to Browse the contents of the 72nd Midyear Technical Conference for what you missed. A special thank you is extended to our site chair, Norman Loney, University of Cincinnati; and our program Co-Chairs Sheryl Sorby, University of Cincinnati and Mary Sadowski, Purdue University, whose efforts resulted in a memorial experience for all. In addition, the Division needs to extend a special thank you to the University of Technology, Jamaica—the staff, students, and faculty—for co-hosting the conference. Their support and the hospitality and generosity they extended us ensured that we were all cared for and that we all were able to maximize our Jamaican experience. Finally, the Division needs to extend a special thank you to Holiday Inn Resort Montego Bay for the warmth and friendliness shown us all. None of the attendees should have left for something more to do or for want of food or drink.

The 73rd Midyear Conference: looks like it is official—Berkeley, CA; Jan 6-8, 2019. Please check back periodically with https://sites.asee.org/edgd/73midyear/ for the due dates and other updates.

Our Annual Conference: Jun 24-27, 2018; Salt Lake City, UT: while it's a little too late to present, there's still plenty of time make your reservations to attend.

The next issue will be a Special Issue of the *Journal*. It will contain papers that were presented during our 72nd Midyear Conference and that appear in the conference proceedings. Given the increasing concerns over redundant or duplicate publication, the papers that will be published in this issue of the *Journal* will be published in accordance with ASEE's Policy on Plagiarism and Duplicate Publication (see https://www.asee.org/about-us/policies/ASEE_Plagiarism_Policy.pdf), which is grounded inASEE's Statement on Engineering Ethics Education (see https://www.asee.org/about-us/the-organization/our-board-of-directors/asee-board-of-directors-statements/engineering-ethics-education).

See you in SLC!

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Message from the Editor

AJ Hamlin, *EDGJ* Editor
Michigan Technological University

In each issue, you can see a list of people on the Journal Editorial Board, the Advisory Board, and Review Board; however, I'd like to take a little more time to thank those listed on that page for their efforts in getting each issue published. Starting with the Editorial Board, I am thankful for the work Raghu Pucha does in overseeing the review process and keeping reviewers on schedule. I am thankful that Judy Birchman has joined the Editorial Board to help with layout editing. I enjoy sorting through the plethora of pictures that Ted Branoff takes of division events to find photos to include in each issue. And I am thankful that Nancy Study manages all the library and member subscriptions, and their dues. I'd like to thank the members of the Advisory Board, especially Bob Chin and Nancy Study, for the guidance and support they provide. I am also thankful for the time and consideration that the Review Board members put into reviewing each article. Their thoughtful comments help improve the content of each issue.

I hope you enjoy this issue!

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EDGD Calendar of Events

Future ASEE Engineering Design Graphics Division Mid-Year Conferences

73rd Midyear Conference – January 2019, Berkeley, California

Site Chair – Dennis Liu

Program Chairs – Tom Delahunty and Daniel Kelly

Future ASEE Annual Conferences

Year	Dates	Location	Program Chair
2019	June 16 - 19	Tampa, Florida	
2020	June 21 - 24	Montréal, Québec, Canada	
2021	June 27 - 30	Long Beach, California	
2022	June 26 - 29	Minneapolis, Minnesota	
2023	June 25 - 28	Baltimore, Maryland	

If you're interested in serving as the Division's program chair for any of the future ASEE annual conferences, please make your interest known.

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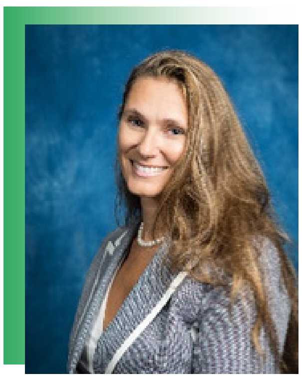
Election Results

According to the Division by-laws (available at: http://edgd.asee.org/aboutus/index.htm), the chair of the Elections Committee shall transmit the results of the election to the Chair of the Division. The Chair shall inform each candidate (including those not elected) of the results of the election for his office and shall transmit the names of the newly-elected officers to the Editor of the *Journal* for publication in the Spring issue of the *Journal*. The chair of the Elections Committee shall report the results of the election to the Division at the annual business meeting. The results for the most recent election are as follows:

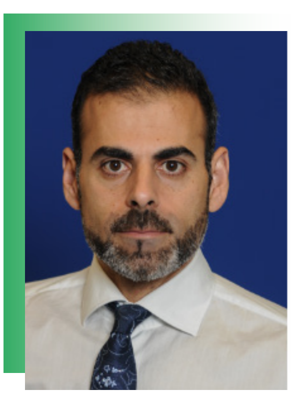
Vice-Chair: Heidi M. Steinhauer



Heidi M. Steinhauer is a tenured Professor of Engineering, Department Chair of the Engineering Fundamentals Department, co-advisor for the only all-women's Baja SAE Team, Founding Member of FIRST (Female Initiative Reaching Success Together), and former director for GEMS (Girls in Engineering, Math, and Science). Dr. Steinhauer's awards include the ABET Presidential Award of Diversity and a three time winner of the Women's Vision Award. She has presented papers at the ASEE Annual Conference, the ASEE Global Colloquium, Research in Engineering Education Symposium, Engineering Design Graphics Division Mid-Year Conference, ASEE-SE Mid-Year Conference, Additive Manufacturers Users Group, and Solid Free-Form Fabrication Symposium.

Her research interests center around the development and assessment of students' spatial visualization skills, development of engineering curriculum that utilize the power of 3D modeling to foster deeper learning by providing students a scaffold to successfully implement an interdisciplinary approach, the effective integration of 3D modeling into engineering design, and the impact of contextualized hands-on applications on student learning and success specifically its impact on the recruitment, retention, and success of women.

Secretary/Treasurer: Petros Katsioloudis



Dr. Petros Katsioloudis is an Associate Professor, Program Leader of Industrial Technology, and Department Chair of the STEM Education and Professional Studies Department at Old Dominion University. Over the last ten years he has demonstrated consistent growth by conducting research on improving teacher performance in STEM education, specifically in the area of engineering graphics and spatial visualization, which results in enhancing a national STEM-educated workforce; collaborative research with scientists and engineers; teaching undergraduate and graduate courses in industrial technology/engineering and technology education; and

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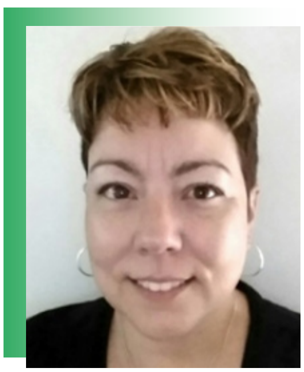
serving in academic and professional communities. As evidence of his accomplishments in both empirical and practitioner-based STEM-related research, Dr. Katsioloudis has published a large number of refereed and/or peer-reviewed articles, As a leader in his professional community, Dr. Katsioloudis served as a grant reviewer for the National Science Foundation; reviews for several scholarly journals, and serves as editor for the RITE section of the Technology and Engineering Teacher Journal. He is also serving as a Review Team member for the ATMAE accreditation agency and conducts site visits at other institutions that seek accreditation. Katsioloudis also served as Treasurer of the National Council of Technology and Engineering Teacher Educators (2011-2014), and Ambassador to Cyprus for the International Technology and Engineering Educators Association (2008-present).

Director of Publications: Nancy Study



Dr. Nancy E. Study is a faculty member of the School of Engineering at Penn State Behrend where she teaches courses in engineering graphics and rapid prototyping, and is the coordinator of the rapid prototyping lab. Her research interests include visualization, standardization of CAD practices, and haptics. Nancy is a former chair of the ASEE Engineering Design Graphics Division and is currently the Circulation Manager and Treasurer of the Engineering Design Graphics Journal. She received her B.S. from Missouri State University, and M.S. and Ph.D. from Purdue University.

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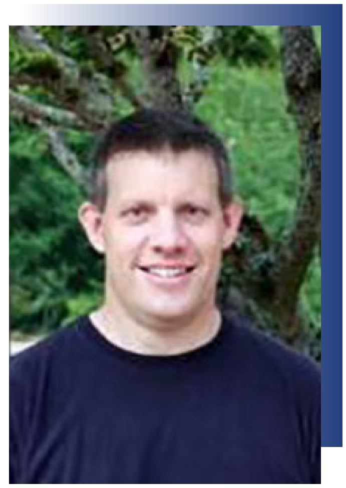
The Chair’s Award

Derek M. Yip-Hoi



David Gill

The 2017 Chair’s Award goes to **Derek M. Yip-Hoi** and **David Gill** from Western Washington University for their paper, “Use of Model-Based Definition to Support Learning of GD&T in a Manufacturing Engineering Curriculum.” Their paper can be downloaded from https://peer.asee.org/use-of-model-based-definition-to-support-learning-of-gd-t-in-a-manufacturing-engineering-curriculum. The Chair’s Award recognizes the outstanding paper presented at an EDGD sponsored ASEE Annual Conference session and carries a cash award.

The award description can be found at:
https://sites.asee.org/edgd/the-chairs-award/

The past awardees list can be found at:
https://sites.asee.org/edgd/the-chairs-award-awardees/

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Secondary Engineering Design Graphics Educators: Credentials, Characteristics, and Caseload

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Virginia Tech

Teena Coats
North Carolina State University

Thomas O. Williams
Virginia Tech

Jeremy V. Ernst
Embry-Riddle Aeronautical University

Abstract

Although the caseload of students with categorical disabilities and limited English proficiency has increased in recent years for secondary engineering design graphics teachers, the level of preparation to teach students with these characteristics has not. Given that teachers must develop inclusive classroom environments for all students, the current state for teacher preparation in regards to working with students with categorical disabilities and limited English proficiency needs to be explored. This study analyzes data from the School and Staffing Survey Teacher Questionnaire to determine the current characteristics, credentialing, and caseload for secondary engineering design graphics teachers. The results show that almost two-thirds of engineering design graphics teachers have a bachelor's degree or less, while half of those have less than a bachelor's degree. In addition, approximately one-third of all engineering design graphics teachers are certified through alternative licensing programs, which include little to no preparation in working with students with categorical disabilities and limited English proficiency. The implications of these results are that as caseloads increase for teachers working with students with categorical disabilities and limited English proficiency, more preparation is required to provide teachers with evidence-based pedagogy in order for these students to achieve their learning potential.

Introduction

Secondary level engineering design graphics courses are an important part of preparing students with the necessary engineering graphics skills and knowledge to be successful in corresponding higher education programs. Many of these concepts are prerequisite for a range of STEM-related career choices that students may choose to pursue in a higher education setting. Even if not a specific course requirement, it can be extremely useful for students to have an understanding of how engineering design graphics knowledge and practices operate both in and outside of STEM-related fields. Addressing the needs of diverse populations within secondary school engineering design graphics courses is critical for STEM fields. Teacher preparation in the area of engineering design graphics needs to address this issue in order to engage all students in these courses. However, current teacher preparation programs do not lend themselves to address the

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needs of the growing diverse classroom that exists in most secondary level engineering design graphics courses (Zirkle, Martin, & McCaslin, 2007).

It is common to find an inclusive group of students within the average general education classroom. In recent years, the numbers of students with categorical disabilities and limited English proficiency (LEP) have increased in all academic disciplines (Casale-Giannola, 2012; U.S. Snyder, de Brey, & Dillow, 2016), with no exception given to skill-based courses such as engineering design graphics (Ernst, Li, & Williams, 2014). As gauged by the School and Staffing Survey Teacher Questionnaire (SASS TQ) datasets, the mean numbers of students in engineering design graphics courses that have a categorical disability or LEP increased between both the 2007-2008 dataset and the 2011-2012 dataset. Students with a categorical disability or LEP make up a significant proportion of the total number of students in the average classroom (Ernst et al., 2014). Under the protection of the Individuals with Disabilities Act (IDEA), millions of students across the education system receive extra supports that allow them to participate in their courses alongside their non-disabled peers. IDEA protects students between the ages of 3 years and 21 years of age in 13 different disability categories which include, autism, deaf-blindness, deafness, emotional disturbance, hearing impairment, intellectual disability, multiple disabilities, orthopedic impairment, other health impairment, specific learning disability, speech or language impairment, traumatic brain injury, and visual impairment (including blindness) (National Dissemination Center for Children with Disabilities, 2012). Students with LEP are defined as “students whose primary language is not English” (Friend & Bursuck, 2014, p. 29) and are not covered under IDEA. These students may be similar to students with categorical disabilities in that they may require extra educational supports. These supports may include bilingual or other instruction outside of the main classroom that provides students the opportunity to learn English while continuing with the standard curriculum in the general classroom setting.

To accommodate the diverse range of students, teachers may consider applying adaptive or universal design features when planning lessons. Universal design features provide an effective approach to student learning that allows educators to deliver instruction through methods that make learning accessible for all students (Michigan State University, 2017; Shaw, 2011). These design features not only apply to classroom instructional time, but also include support materials that influences all areas of the students’ learning experience such as videos, labs, fieldwork, and computer technology (Burgstahler, 2011). Under guidelines set by IDEA, schools assess and decide what supports are needed for each student through the collaborative work of teachers, student disability specialists, and parental involvement. This method of assessment can lead to students with similar diagnoses receiving a wide variety and levels of support in a classroom environment. Most of this responsibility falls on the teacher to create the necessary environment needed for students with categorical disabilities and LEPs based on the student’s Individualized Education Plan (IEP). It is difficult in any educational setting to

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know exactly what services to provide in order to create an equal opportunity learning environment, even when catering to the student's IEP. However, the teacher can provide several accommodations in the classroom without completely restructuring the physical setting (Green & Casale-Giannola, 2011; Tomlinson, 1999). Inclusive environments may utilize differentiated instruction, collaborative activities, or common adaptive technologies (Leiding, 2009).

There is little research showing how the differences in teacher preparation relate to the ability to teach students with categorical disabilities. Every teacher preparation program is different, but prior research concludes the average teacher preparation program provides minimal courses in preparing teachers to work with students with categorical disabilities (Zirkle et al., 2007). Preparation programs for Career and Technical Education (CTE), the category under which Engineering Design Graphics falls, teachers may receive even less training for teaching students with categorical disabilities due to the number of courses needed to prepare them for the diverse range of content knowledge they need to teach (Casale-Giannola, 2012). In most teacher preparation programs, it is common for there to be only one course that focuses on managing students with accommodations, IEPs, or 504 plans. The primary focus of student accommodations covered during preparation courses include differentiating assessments, such as large print, the use of read-aloud assignments, or individualized testing facilities. However, student accommodations can include a much larger variety of possibilities. These could include but are not limited to modified instructional methods (e.g., repeat and summarize key points, use audiovisual aids, conduct oral testing or alternative assessments), equipment (e.g., hand or foot controls, adjustable tables); or adapted curriculum objectives to meet specific student needs (Missouri State Department of Elementary and Secondary Education, 1999). Very few teachers will have the opportunity to practice the necessary classroom management that comes along with having multiple students with categorical disabilities in their classrooms (Shaw, 2011), much less in a unique environment that can be found in CTE courses that do not subscribe to the many of the same traditional situations that are found in core subject classrooms. Some studies suggest that regardless of what a teacher learns within a teacher preparation program, it is the personal opinion of the teacher that dictates how a classroom should operate when there are students with categorical disabilities (Jordan, Schwartz, & McGhie-Richmond, 2009). For engineering design graphics teachers, much of the content has been taught using similar practices for many years, which makes it difficult for some teachers to adapt to the changing needs of their classrooms, creating unique challenges for actively including all students (White, 2015).

Most secondary level teachers earn a traditional teaching license. The most traditional path is to attain a teaching license through attending a four-year university. By obtaining a Bachelor's degree in a specific teaching content area such as science, math, or elementary education, teachers gain content knowledge as well as educational peda-

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gogical knowledge. However, there is a shorter, less costly option for those that wish to pursue teaching after spending time in industry, or another career. This is an alternative certification program. These programs prepare an individual to take the knowledge used in their previous jobs, and relay it in a way that relates to the curriculum at a given age level. The content of these programs can vary greatly based on the type, content area, and the state in which it occurs. However, the hope is that an individual should be adequately prepared to teach after participating in an alternative certification program (Bowen, 2013). Depending on the program, a Bachelor's degree may not be required to participate in an alternative certification program. The number of years in practical experience in the field can be equated to schooling experience, meaning in some cases the education level of these teachers may not exceed an associate's degree. Engineering design graphics courses teach skills in areas such as drafting or CADD (computer aided drafting and design) and are typically taught by teachers from a variety of backgrounds. Many of these teachers gained their knowledge on the subject from their years spent in careers where they used these skills on a daily basis.

There is limited research describing whether the ability to teach students with categorical disabilities is different based on a teacher's certification pathway. However, regardless of the certification process, a large number of teachers do not have a full teaching certification when they begin teaching (Ruhland & Bremer, 2003). However, in most traditional programs, content about teaching students with categorical disabilities is typically covered in at least one course. Generally, in an alternative program, which varies based on state and district, there is not an explicit course covering how to teach students with categorical disabilities. Despite the presence of these courses, most teachers, regardless of certification pathway, do not feel adequately prepared to teach students with categorical disabilities (Boyer & Mainzer, 2003). Many reported they needed ongoing support when teaching students with categorical disabilities and would have preferred receiving this during the teacher preparation program, as well as through targeted professional development opportunities (Casale-Giannola, 2012; Ruhland & Bremer, 2003). Teachers that participate in these professional development opportunities often feel more prepared to teach students with categorical disabilities than the teachers that do not (Jobling & Moni, 2004). Inclusive classrooms and the elevated expectations for all students call for a change in preservice teacher preparation, both traditional and alternative, as there is a need to include students with categorical disabilities in all areas of education, and for them to learn alongside their non-disabled peers (Harvey, Yssel, Bauserman, & Merbler, 2010).

More information is needed to describe the preparation of engineering design graphics teachers and their qualifications for working with diverse populations of students. Ernst et al. (2014) reported the number of students with LEP and categorical disabilities is increasing in classrooms of engineering design graphics teachers. The goal of the current study is to reinforce the data about the categorical disability caseload and to provide

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additional data on the descriptive nature of teacher demographics, teaching locations, teaching levels, and teacher preparations characteristics for engineering design graphics teachers in the United States. Therefore, this paper reports evidence-based information for the following research questions:

1. What are the demographic characteristics of Engineering Design Graphics teachers?
2. What are the credentials of Engineering Design Graphics teachers?
3. What is the caseload of student population features and characteristics within Engineering Design Graphics teachers' classrooms?

Methodology

Instrumentation

This study employed data from the most recent SASS TQ survey. The SASS TQ consists of five questionnaires: a School District Questionnaire, Principal Questionnaire, School Questionnaire, Teacher Questionnaire, and a School Library Media Center Questionnaire. This study analyzed data from the SASS TQ restricted-use data files that contains variables not available in the public-use data set. There are 85 questions comprising nine sections. According to Tourkin et al. (2010, p. 1):

> "The School and Staffing Survey Teacher Questionnaire is conducted by the National Center for Education Statistics (NCES) on behalf of the U.S. Department of Education in order to collect extensive data on American public and private elementary and secondary schools. The SASS TQ provides data on the characteristics and qualifications of teachers and principals, teacher hiring practices, professional development, class size, and other conditions in schools across the nation. The overall objective of the SASS TQ is to collect the information necessary for a comprehensive picture of elementary and secondary education in the United States. The SASS TQ was designed to produce national, regional, and state estimates for public elementary and secondary schools and related components and is an excellent resource for analysis and reporting on elementary and secondary educational issues."

Sampling Weights

The SASS TQ survey design utilizes sampling weights that allow researchers to generalize the data to the sampled population (Thomas, Heck, & Bauer, 2005). Sampling weights for elementary schools, secondary schools, and teachers used in the SASS TQ "take into account the school's selection probability, to reduce biases that may result from unit non-response, and to make use of available information from external sources to improve the precision of sample estimates" (Kena et al., 2015) and to help estimate national public school teacher populations while maintaining the original sample sizes.

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Due to the complexity of the SASS TQ survey design, stratification of data (sampling each subpopulation independently), clustering (teacher selection within schools), and oversampling (over selection of educators containing certain characteristics) techniques are used to maintain the validity of the data. Direct estimates of sampling errors, in this type survey, will characteristically underestimate the sampling variability in the summary statistics and distort test of statistical significance (Finster, 2013; Hahs-Vaughn, 2005; Thomas & Heck, 2001). NCES developed weights to balance this bias and replicate weights for the SASS TQ design to be incorporated in a study to construct unbiased population assessments. Fundamentally, these weights help to summarize and correct for the probability of selection and are inversely proportional to the probability of selection (Finster, 2013; Tourkin et al., 2010).

Participant Selection

In this study, the participants who gave a subject-matter code 246 (CADD and Drafting) to Question 16 in the 2011-2012 SASS TQ, "This school year, what is your MAIN teaching assignment field at THIS school?", were identified as engineering design graphics teachers. The resulting weighted number of teachers was 12,240.

Variables Analyzed

Several demographic variables were analyzed collectively to answer Research Questions 1 and 2. To answer Research Questions 1, the following variables were analyzed; gender, age, teaching experience, employment status, race, ethnicity, and teaching location, including urbanicity, region, and school level. To answer Research Question 2, the following variables were analyzed; level of education, certification status, route to certification, and qualification status. Research Question 3 analyzed the caseload for categorical disabilities, including the number of students with recognized disabilities, the number of students with LEP, and the service load of at-risk students with categorized disabilities and LEP combined.

Procedure

This study consisted of a secondary analysis of the most recent SASS TQ restricted-use license dataset to present a national profile of engineering design graphics teachers. Specified reporting protocols were followed and data findings were submitted to the Institute for Educational Sciences (IES) for approval and authorization for release. Data were analyzed using SPSS 23.0. Data for the descriptive analyses were weighted using the variable Teacher Final Sampling Weight (TFNLWGT). All n's were rounded to the nearest 10 to assure anonymity per National Center for Educational Statistics (NCES) and IES requirements and data in the tables may not add up to the total N initially reported due to rounding adjustments. When any estimates did not meet the NCES or IES reporting protocols, they were not reported in the tables and were noted with an asterisk (Dinkes, Cataldi, Lin-Kelly, & Snyder, 2007; Robers, Kemp, Rathbun, Morgan, & Snyder, 2014).

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Results

To answer Research Question 1, the variables analyzed include gender, age, teaching experience, employment status, race, ethnicity, and teaching location.

Gender, Age, Teaching Experience, and Employment Status

Demographic information concerning teacher gender, age, teaching experience and teaching status is presented in Table 1. Engineering design graphics teachers are predominately male and full-time teachers. Their age and teaching experience suggests that these teachers are in the middle of their expected teaching careers.

Table 1
Percentage of engineering design graphics teachers according to gender, age, teaching experience, and status.

	Male	Female	Mean Age	Mean Experience	Full-time Status
Engineering Design Graphics Teachers	93.7	6.3	48.12	14.74	97.1

Race and Ethnicity

Teachers' self-reported race is presented in Table 2. This information was collected for the purposes of establishing a demographical make-up of engineering design graphics teachers. Racial category descriptors are presented verbatim as they appeared on the SASS TQ survey. Participants were allowed to make more than one selection. However, the majority of the participant's data reflected one category. The most prevalent self-selected racial category represented was White, followed by Hispanic and Black or African-American. Asian, Native Indian or Alaskan Native, and Native Hawaiian or Other Pacific Islanders were the least prevalent self-selected racial categories with numbers low enough not to meet IES reporting requirements. As noted, data for certain descriptors did not meet IES and NCES reporting standards and were not presented in the tables. The table total does not equal 100 percent due to the remainder (2.9%) of the participants choosing two or more categories.

Table 2
Percentage of engineering design graphics teachers on self-reported racial categories.

	Hispanic	White	Black or African-American	Asian	Native Hawaiian or Other Pacific Islander	American Indian or Alaska Native
Engineering Design Graphics Teachers	4.2	89.8	3.1	*	*	*

Note. Descriptors were taken directly from the SASS TQ
* Did not meet IES reporting requirements.

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Location

The location of engineering design graphics teachers was examined through urbanicity, region, and school type. These results are presented in Table 3. The majority of engineering design graphics teachers teach in rural and suburban areas. Towns had the lowest percentage. The south had the highest percentage engineering design graphics teachers and the west had the lowest. Secondary or high school settings were the most predominate settings for engineering design graphics teachers.

Table 3
Location of engineering design graphics teachers in percentages.

	Urbanicity		
City	**Suburban**	**Town**	**Rural**
21.0	30.1	13.3	35.8
	Region		
Northwest	**Midwest**	**South**	**West**
23.6	26.5	37.8	12.0
	Four category school level		
Primary	**Middle**	**High**	**Combined**
*	5.2	88.7	6.0
	Two category school level		
	Primary	**Secondary**	
	*	99.5	

* Does not meet IES reporting requirements.

Level of Education

Table 4 shows the highest level of education that was reported. It should be noted that only the highest degree obtained is reported. It does not include the reporting of multiple or similar degrees. The Bachelor's degree tended to be the most prevalent degree among engineering design graphics teachers. However, there is a large percentage of engineering design graphics teachers who have an associate degree when compared ot

Table 4
Percentage of engineering design graphics teachers highest degree obtained.

	Associate	**Bachelors**	**Masters**	**Educational Specialist**	**Doctorate**
Engineering Design Graphics Teachers	30.2	37.5	24.0	5.3	5.1

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Certification Status, Route, and Qualification Status

Table 5 shows the certification status, certification route, and qualification status of engineering design graphics teachers. Approximately 81 percent of the teachers are fully-certified and about one-third enter into the profession through alternative programs. The SASS TQ defines alternative programs as a program that was designed to expedite the transition of non-teachers to a teaching career, for example, a state, district, or university alternative certification program.

Table 5
Percentage of Engineering Design Graphics Teachers certification, and career path entry.

	Regular or standard state certificate	Alternative certification program	Traditional certification program
Engineering Design Graphics Teachers	81.0	34.6	65.4

Categorical Disability Caseload

Regarding students with categorized disabilities, the results are shown in Table 6. Engineering design graphics teachers reported a mean of 12.45 students with categorized disabilities, a mean of 3.58 of students with LEP, and approximately 16 students with at-risk indicators on their caseload.

Table 6
Engineering Design Graphics Teachers caseloads.

	Mean Categorical	Mean LEP	Service Load
Engineering Design Graphics Teachers	12.45 SD =10.75	3.58 SD = 10.06	16.03 SD = 19

Conclusions and Implications

Over the past decade, research shows an increase in the caseload for engineering design graphics teachers for students with categorical disabilities and LEP resulting in an even higher level need for familiarity and preparation, through either teacher education programs, alternative certification, or professional development opportunities (Ernst et al., 2014). The results of the current study highlight that 30.2% of engineering design graphics teachers have less than a bachelor's degree as their highest level of education. This is notable when factoring the adequacy of preparation teachers received regarding preparedness to teach students with categorical disabilities and LEP. Another 37.5% of engineering design graphics teachers have been credential through bachelor's degrees. Therefore, approximately 68% of all engineering design graphics teachers have a bach-

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elor's degree or less. With many undergraduate teacher preparation programs struggling to find the flexibility and credits hours to include pedagogical courses for teaching students with categorical disabilities, the majority of engineering design graphics teachers probably do not have adequate training to confidently and effectively teach the rising population of students with categorical disabilities and LEP. In addition, 34.6% of engineering design graphics teachers reported being certified through an alternative certification program. Very rarely would an alternative certification program contain content about teaching strategies for students with categorical disabilities or LEP.

As the number of students with categorical disabilities and LEP increases within the classroom, improving the knowledge of teaching strategies specifically for these students is becoming critical. Using evidence-based pedagogy is required for these students to achieve their learning potential. This paper specifically addresses these needs for engineering design graphics teachers. By providing this information, additional research can be designed to help understand how engineering design graphics teachers can be better prepared to work with students with categorical disabilities and LEP. The results of this analysis demonstrates that, due to the types of certifications and highest level of degree earned, engineering design graphics teachers may be lacking the necessary pedagogical knowledge to teach students with categorical disabilities and LEP. Further research will help determine the specific knowledge level of engineering design graphics teachers as well as how teacher preparation programs are providing the necessary pedagogical content in regards to working with these groups of students.

References

Bowen, B. D. (2013). Measuring teacher effectiveness when comparing alternatively and traditionally licensed high school technology education teachers in North Carolina. *Journal of Technology Education*, 25(1), 80-98.

Boyer, L., & Mainzer, R. W. (2003). Who's teaching students with disabilities? A profile of characteristics, licensure status, and feelings of preparedness. *Teaching Exceptional Children*, 35(6), 8-11.

Burgstahler, S. (2011). Universal design: Implications for computing education. *ACM Transactions on Computing Education*, 11(3), 19.

Casale-Giannola, D. (2012). Comparing inclusion in the secondary vocational and academic classrooms: Strengths, needs, and recommendations. *American Secondary Education*, 40(2), 26-42.

Dinkes, R., Cataldi, E. F., Lin-Kelly, W., & Snyder T. D. (2007). Indicators of school crime and safety: 2007. National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, and Bureau of Justice Statistics, Office of Justice Programs, U.S. Department of Justice. Washington, DC.

Ernst, J. V., Li, S., & Williams, T. O. (2014). Secondary engineering design graphics educator service load of students with identified categorical disabilities and limited English proficiency. *Engineering Design Graphics Journal*, 78(1), 1-10.

Finster. M. P. (2013). *Teachers' job satisfaction, organizational commitment, turnover intentions, and actual turnover: A secondary analysis using an integrative structural equation modeling approach* (Doctoral Dissertation). Retrieved from https://digital.lib.washington.edu/researchworks/handle/1773/23621.

ISSN: 1949-9167

Friend, M., & Bursuck, W. D. (2014). *Including students with special needs: a practical guide for classroom teachers* (7th ed.). Boston: Pearson.

Green, L. S., & Casale-Giannola, D. (2011). *40 active learning strategies for the inclusive classroom, grades K–5*. Thousand Oaks, CA: Corwin.

Hahs-Vaugh, D. L. (2005). A primer for using and understanding weights with national datasets. *The Journal of Experimental Education*, 73(3), 221-248.

Harvey, M. W., Yssel, N., Bauserman, A. D., & Merbler, J. B. (2010). Preservice teacher preparation for inclusion: An exploration of higher education teacher-training institutions. *Remedial and Special Education*, 31(1), 24-33.

Jobling, A., & Moni, K. B. (2004). 'I never imagined I'd have to teach these children': Providing authentic learning experiences for secondary pre-service teachers in teaching students with special needs. *Asia-Pacific Journal of Teacher Education*, 32(1), 5-22.

Jordan, A., Schwartz, E., & McGhie-Richmond, D. (2009). Preparing teachers for inclusive classrooms. *Teaching and Teacher Education: An International Journal of Research and Studies*, 25(4), 535-542.

Kena, G., Musu-Gillette, L., Robinson, J., Wang, X., Rathbun, A. Zhang, J., . . . & Velez, E. D. (2015). *The condition of education 2015*. (NCES 2015-144). Washington, DC: U.S. Department of Education, National Center for Education Statistics. Retrieved from nces.ed.gov/pubs2015/2015144.pdf.

Leiding, D. (2009). *Reform can make a difference: A guide to school reform*. New York, NY: Rowman & Littlefield Education.

Michigan State University (2018, August 12). Universal design for learning (UDL). Retrieved from http://insideteaching.grad.msu.edu/best-fit-4-reasons-to-use-universal-design-for-learning-udl/

Missouri State Department of Elementary and Secondary Education. (1999). *Transition: School to post-school activities: Access to vocational education for students with disabilities*. Issues in Education. Technical Assistance Bulletin. Jefferson City, MO: Division of Special Education. (ERIC Document Reproduction Service No. ED436895).

National Dissemination Center for Children with Disabilities. (2012, March). *Categories of disability under IDEA*. Retrieved from http://nichcy.org/wp-content/uploads/docs/gr3.pdf

Robers, S., Kemp, J., Rathbun, A., Morgan, R. E., & Snyder, T. (2014). *Indicators of school crime and safety: 2013* (NCES 2014-042/NCJ 243299). Washington, DC: National Center for Education Statistics, U.S. Department of Education, and Bureau of Justice Statistics, Office of Justice Programs, U.S. Department of Justice. Washington, DC.

Ruhland, S. K., & Bremer, C. (2003). Perceptions of traditionally and alternatively certified career and technical education teachers. *Journal of Vocational Education Research*, 28(3), 285-302.

Shaw, R. A. (2011), Employing universal design for instruction. *New Directions for Student Services*, (134), 21-33.

Snyder, T. D., de Brey, C., & Dillow, S. A. (2016). *Digest of education statistics 2015*, (NCES 2016-014), Chapter 2. Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Thomas, S. L. & Heck, R. H. (2001). Analysis of large-scale secondary data in higher education research: Potential perils associated with complex sampling designs. *Research in Higher Education*, 42(5), 517-540.

Thomas, S. L., Heck, R. H., & Bauer, K. W. (2005). Weighting and adjusting for design effects in secondary data analyses. *New Directions for Institutional Research*, 2005(127), 51-72.

Tomlinson, C. A. (1999). The differentiated classroom: Responding to the needs of all learners. Alexandria, VA: Association for Supervision and Curriculum Development.

ISSN: 1949-9167

Tourkin, S., Thomas, T., Swaim, N., Cox, S., Parmer, R., Jackson, B., Cole, C., & Zhang, B. (2010). *Documentation for the 2007–08 Schools and Staffing Survey (NCES 2010-332)*. U.S. Department of Education. Washington, DC: National Center for Education Statistics. Retrieved June 17, 2014 from http://nces.ed.gov/pubsearch

White, D. W. (2015). Engaging students regarding special needs in technology and engineering education. *Technology and Engineering Teacher*, 75(2), 8-12.

Zirkle, C. J., Martin, L., & McCaslin, N. L. (2007). *Study of state certification/licensure requirements for secondary career and technical education teachers*. (ERIC Document Reproduction Service No. ED508968). National Research Center for Career and Technical Education.

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Sustainable Design: Integrate the Creative Thinking and Innovation into Graphical Communications

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Abstract

Engineering programs need to prepare the next generation of engineering professionals for tackling sustainability challenges that impact the social, environmental, and economic progress of the nation. This paper describes how the sustainable design concept was integrated into a freshman-level engineering gateway course that emphasized creative thinking and innovation through an open-ended team project. The goal of the study is to improve students' study skills to prepare them to be the next generation of engineering professionals. The expected outcomes are increased and improved innovative thinking, communication, and teamwork skills. A questionnaire-based methodology is used to assess the success of the study using data collected over three years. The assessment results indicated that students liked the sustainable design project and that their innovative thinking, communication, and teamwork skills were improved by it. A summary of lessons learned during the study is included and a future plan is discussed.

Introduction

Policy-makers worldwide have identified that today's engineering education should prepare the next generation of engineering professionals to undertake applied sustainability challenges that impact the social, environmental, and economic progress of the nation (ASEE, 1999; United Nations, 2002a, United Nations, 2002b); National Academy of Engineering, 2004, Byers, Seelig, Sheppard, & Weilerstein, 2013). Students should be able to apply the knowledge they learned in the class to solving real-world problems and applying nontraditional, creative thinking to sustainable engineering design concerns (Beiler, 2014). The importance of sustainability in engineering education is also recognized in the engineering accreditation criteria developed by the Accreditation Board of Engineering and Technology (ABET). ABET accreditation guidelines for 2014-2015 (ABET, 2013) include sustainability in at least two of the a-k student outcomes required for all engineering programs:

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and **sustainability**.

(h) the broad education necessary to understand the impact of engineering solutions in a global, **economic, environmental, and societal** context.

Criterion (c) clearly mentions sustainability, while criterion (h) refers to economic, environmental, and societal context, which are three components of sustainability.

Sustainability is a powerful, yet abstract, concept. The World Commission on Environment and Development's (WCED) (1987) originally defined sustainable development

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as "providing for human needs without compromising the ability of future generations to meet their needs." However, this definition is hard to measure. The triple bottom line definition is often used in business and is more useful in assessing the sustainability of the engineering design since it measures economic cost, environmental impact, and social acceptability (Barrera-Roldan & Saldivar-Valdes, 2002).

Graphical Communications, an engineering fundamentals course, is designed to familiarize students with the basic principles of drafting and engineering drawing. It improves three-dimensional visualization skills of the students and teaches them the fundamentals of a computer aided design program — CATIA. Much of the instruction has traditionally focused on knowledge and comprehension, low levels of Bloom's taxonomy (Bloom, 1956). However, students' ability to use this knowledge and comprehension to explore real engineering design is unknown. Their project management ability, creative thinking, leadership, effective communication, and teamwork skills, which are criteria of the ABET (2013) program and are essential for the professional practice of engineering, are typically not assessed.

Previous research has shown that the integration of the sustainable design idea into the design process can provide students with an opportunity to learn about many factors that go into engineering design and that emphasized the importance of collaboration between students of various engineering disciplines (Bielefeldt, Jones, Price, Grahame, & Gillen, 2016; Price & Aidoo, 2013). The students can learn design process that emphasized environmental, economic, and social responsibility (Paudel & Fraser, 2013; Pfluger & Schulte Graham, 2014; Weber et al., 2014). This paper describes how the sustainable design concept has been integrated into a freshman-level engineering gateway course to emphasize creative thinking and innovation through an open-ended team project (Doyle, Baetz, & Lopes, 2009; Hertzog & Swart, 2015). The goal of the study is to build students' study skills to prepare them to be the next generation of engineering professionals. The expected outcomes are an increase in innovative thinking and an improvement in communication, leadership, and teamwork skills.

A questionnaire-based methodology was used to assess the success of the study. Phase reports and final reports were required to evaluate their project management ability, innovation ideas, problem solving, and written communication skills. Peer evaluation was used to determine their collaboration, leadership, and teamwork skills. Team evaluation was done to test their effectiveness of oral communication. The assessment results indicate that students' engagement with the sustainable design project increased and their innovative thinking, communication, and leadership. It was found that teamwork skills improved in the sustainable design project over the three years data were collected and analyzed. A summary of lessons learned during the study is included, and a future plan is discussed.

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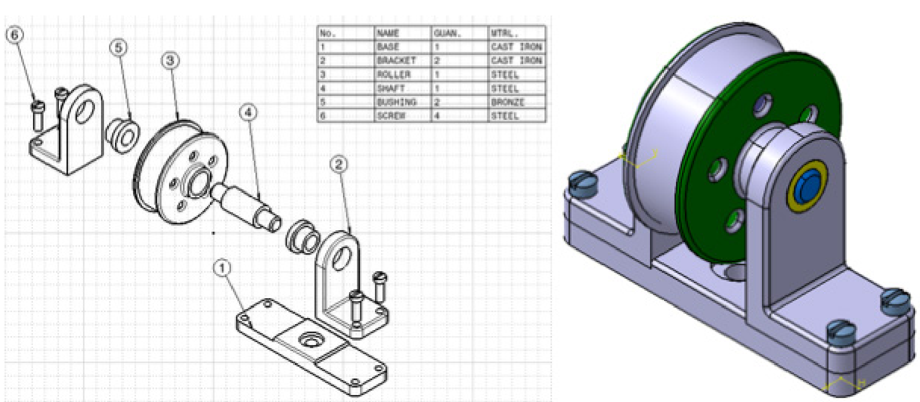
Course Curriculum and Structure

The goal of the Graphical Communications course is to familiarize students with the basic principles of drafting and engineering drawing, to improve three-dimensional visualization skills, and to teach the fundamentals of computer aided design using CATIA. After course completion, students will know the character and application of the various lines used in engineering drawings; be able to relate a scaled drawing to actual size and be able to produce drawings to scale; develop the ability to make acceptable freehand sketches with special understanding of the importance of proportions; know the principles of orthographic projection and apply these principles to construct multi-view drawings; understand the principles of isometric projection and apply these principles to isometric drawings; understand and draw auxiliary views; understand and draw interior views of an object as a section view; develop the techniques and rules of dimensioning and tolerances, and be able to apply these skills to a drawing; be able to read and understand a basic blue print; be able to understand and use CATIA as a computer aided drafting tool to produce multi-view, isometric, auxiliary and section views.

As a three-credit-hour semester course, students meet the instructor twice a week with each class lasting two hours. The first hour of each class is the scheduled lecture time; after the lecture, students are encouraged to use the rest of class time to ask questions and complete their assigned homework. During the 14-week semester, students learn the principle of orthographic projections and apply the principles to multi-view drawings by hand in the first four weeks. CATIA, a 3-D computer aided parametric design tool, is introduced after the hand drawing, followed by auxiliary views, section views, dimensioning, and tolerances. A final individual assembly project is given to the students to test their problem-solving skills under the direction of the instructor. Students need to complete at least ten-part assembly and constructing the final item following the constraint requirements. Figure 1 and Figure 2 show the exploded and isometric views of two previous individual final projects.



A   B

Figure 1. A: Exploded view of a roller guide, B: 3-D view of a roller guide.

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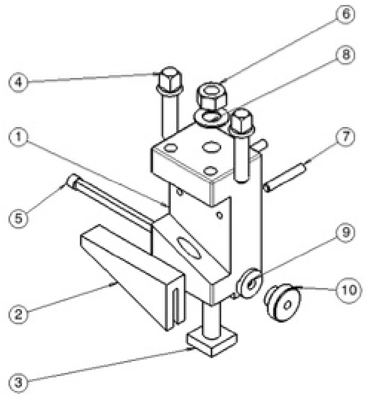
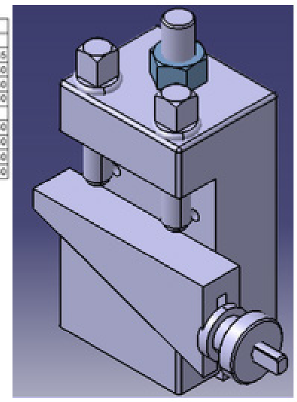


PART #	PART NAME	REQ'D	MAT
1	TOOL POST BODY	1	CI
2	WEDGE	1	SAE 1045
3	BOLT	1	SAE 1040
4	TOOL POST SCREW	2	SAE 1040
5	ADJUSTING SCREW	1	SAE 1040
6	HEX NUT	1	-
7	SET SCREW	2	SAE 1040
8	WASHER	1	SAE 1040
9	WASHER	1	SAE 1040
10	ADJUSTING NUT	1	SAE 1040



A B

Figure 2. A: Exploded view of a roller guide, B: 3-D view of a roller guide.

At the end-of-course evaluation we found that students could follow the directions and accomplish the individual project on time. However, they felt a guided project lacked sufficient challenge, and that they would like to design a more complex model by themselves. According to the Bloom's taxonomy (1956), a guided individual project is considered as an application which can be used to test student problem solving ability as well as satisfying the ABET requirement. However, at this point in the students' education they typically have difficulty transferring material learned in the classroom to real life situations. They tended to become frustrated when they are confronting an open-ended design (Farris & Lane, 2005). To address this situation, investigate 21st century challenges, and the demand for creative and innovative thinking, an open ended sustainable design project was initiated starting spring semester of 2011. Students are required to design a product existing in today's market, then consider how to improve it by incorporating the concept of sustainability into their design, which involves engineering design feasibility, environmental impact, social and political consideration, and economic and financial feasibility.

In teams of two to four students, with self-selected team partners, students are required to finish their design project within six to eight weeks. Each student is expected to first present their design idea and innovative/creative methods for solving the problem to the instructor for approval. Students are encouraged to seek their teammates and determine the design idea from an approved list. To address the importance of sustainable design, and the philosophy and the intent of sustainable design, some real-world examples are instilled in students by showing a series of screencasts produced by Autodesk (2012) during class time.

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Students are required to perform research to support their innovative design, which must emphasize environmental, social, political, economic, financial, and engineering skills. The product must involve sustainable design concepts such as design for disassembly, design for repair, design for recycling, design for upgrade, and design for remanufacturing. Each assembled product includes at least ten unique parts and each part must be designed individually. The role of the instructor is as a facilitator to ensure student projects are delivered on time; direct guidance is limited to a minimum. In addition to their self-scheduled project time outside of the class, specific class time is dedicated to their project study as well, in which they can collaborate with their teammates to discuss the problems, and work on the project. They are encouraged to think outside the box and systematically design their project. All dimensioned drawing sheets, 3-D part models, and PowerPoint slides must be submitted online before the start of the presentation on the last day of the class. On the last day of the class, students appear in professional dress to present their work as a team. Each presentation lasts 8-10 minutes, and is followed by 2 minutes of question and answer time.

Confidential peer evaluation forms are used to evaluate their own performance and that of their teammates based on contribution and quantity of the work, interaction and collaboration of the teamwork, problem solving skills and quality of the work, time management, and willingness to be a team player. Team evaluations are completed by students in the class on the presentation day. Team evaluation criteria include presentation organization, slides content, presentation skills, aesthetics of the presentation, and team member participation. They are strongly encouraged to leave comments, as well as recommendations, to support their evaluation. At the end of the presentation, the instructor summarizes the student projects. A questionnaire-based methodology is used to assess the success of the study.

In spring semester, 2011, the multiple view drawings were not required, and students only need to finish the part design and the assembly design. Starting fall semester, 2011, detailed drawings were required, and students were required to show the multiple views, isometric view, and the dimensions on the drawing sheet for each individual part. Since fall 2012, in addition to the above assigned tasks, students are required to submit two sets of the design files. One is the original design based on the current existing product in the market, and the other one is the redesigned model to show the sustainable design. Students also must submit a written report as a team to document their research findings, design process, timeline, cost analysis, and conclusion. Each student additionally submits an individual logbook to document his/her work schedule and the tasks finished following their team timeline.

Project Study Outcomes

From spring 2011 through spring 2014, there were 289 students enrolled in the course, over 77% of which are male, 58% freshmen, and 62% aerospace engineering majors. The basic demographic breakdown for the class population can be found in Table 1.

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Table 1
Student background characteristics from the spring 2011 to the spring 2014.

	Spring 11		*Fall 11*		*Spring 12*		*Fall 12*		*Spring 13*		*Fall 13*		*Spring 14*	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Gender														
Male	21	81	30	86	41	77	75	82	69	83	48	79	28	85
Female	5	19	5	14	12	23	17	19	14	17	13	21	5	15
Total	26	100	35	100	53	100	92	100	83	100	61	100	33	100
Academic level														
Freshman	15	58	24	69	39	74	61	66	49	59	45	74	19	58
Sophomore	11	42	5	14	10	19	17	19	25	30	11	18	10	30
Junior	0	0	4	11	2	4	7	8	2	2	3	5	3	9
Senior	0	0	2	6	2	4	7	8	7	8	2	3	1	3
Total	26	100	35	100	53	100	92	100	83	100	61	100	33	100
Major														
Aerospace	22	85	27	77	38	72	65	71	53	64	38	62	27	82
Civil	1	4	0	0	1	2	1	1	0	0	1	2	1	3
Mechanical	3	12	3	9	6	11	12	13	17	21	8	13	2	6
Still exploring	0	0	2	6	4	8	2	2	7	8	6	10	1	3
Other (non-engineering)	0	0	3	9	4	8	12	13	6	7	8	13	2	6
Total	**26**	**100**	**35**	**100**	**53**	**100**	**92**	**100**	**83**	**100**	**61**	**100**	**33**	**100**

Note: Percentages are rounded to the nearest whole number.

The success of the project was evaluated through ABET outcomes *(a), (c), (g), (h), (k)*. ABET outcomes *(a)* and *(h)* are common assessment completed by all sections of Graphical Communications course. ABET outcomes *c*, *g*, and *h* are additional criteria of this project study. The evaluation rubric is shown in Table 2. ABET outcome *(a)* evaluates student understanding of freehand sketching and its application in the final project. ABET outcome *(c)* applies to student's understanding of sustainability and the application in the final project, specifically evaluation of the final report and presentation. ABET outcome *(g)* assesses student's oral and written communication skills and their teamwork skills based on the rubrics provided to them. ABET outcome *(h)* evaluates how to reflect the sustainability concept in their CATIA design, specifically parts and product are evaluated. ABET outcome *(k)* focuses on overall CATIA model design and drawing documentation. Some selective project topics are listed in Table 3.

Figures 3-6 show the rendered pictures and exploded views of student team projects in each year.

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Table 2
Evaluation rubric of the final project.

ABET Outcomes	Key Indicators	Excellent 2	Satisfactory 1	Unsatisfactory 0
(a) Ability to apply knowledge of mathematics, science and engineering.	Use lines, scaling, orthographic, isometric, and special views to depict design information. Apply dimensions and notes on the detailed drawing to communicate design information.	The key indicators listed are nearly always completed correctly.	The key indicators listed are mostly completed correctly.	The key indicators listed are frequently/ mostly not completed correctly.
(c) Ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.	Identify the problem and conduct the research to seek the feasibility solution through exploring environmental, economic, social impacts.	Is familiar with the concept of the sustainability and respects the impact of engineering solutions on the environment, economics, and society.	Is aware of the concept of the sustainability and the impact of engineering solutions on the environment, economics, and society.	Is unaware of the concept of the sustainability and the impact of engineering solutions on the environment, economics, and society
(g) Ability to communicate effectively.	Demonstrate effective oral and written communication skills and teamwork ability.	Create a comprehensive team report, demonstrate effective teamwork ability, and clearly present the project as a team.	Report missing some contents, some teamwork issues, and presentation is not clear.	Report missing most of contents, have significant team issues, and no presentation.
(h) Broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context.	Analyze the problem and apply the sustainability concept to CATIA design.	Create a new model with a design for disassembly, repair, recycling, upgrade, or remanufacturing within realistic constraints.	Create a new model with a design for disassembly, repair, recycling, upgrade, or remanufacturing without realistic constraints.	Create a new model with no sustainability involved.
(k) Ability to use the modern engineering tools necessary for engineering practice.	CATIA was used in the creation or design and documentation of parts and assemblies.	CATIA was used and documented, and used correctly.	CATIA was used and documented, but with two minor evident modeling or documentation issues.	CATIA was not used and documented, but with more than two evident modeling or documentation issues.

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Table 3
Selected student projects list.

Eco-friendly skateboard	Floor lamp
Piano keyboard	Eco-friendly guitar
Adjustable scooter	Wheeled luggage
Self-powered gym bike	Microscope
Ergonomic pen	Hover board
Lighter and flexible unicycle	Monitor mount
Ergonomic mouse	Comfortable office chair
Light year jetpack	User-friendly fire extinguisher
Interchangeable watch	Space relay power system
Eco RC helicopter	Fold-out-desk office chair
User-friendly keyboard	Life-proof smart phone case
Lighter pencil sharpener	Eco-friendly bicycle
Computer desk lamp redesign	Durable mechanical pencil
DJ controller	Computer desk lamp redesign
Solar powered wheelchair	Computer station

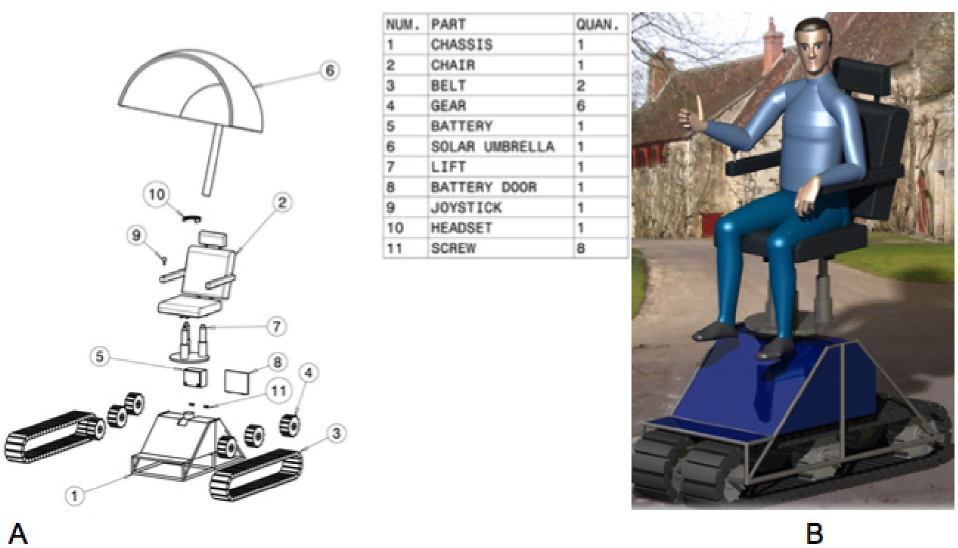

Figure 3. A: Rendered solar powered wheelchair, B: Rendered wheel chair from 2011.

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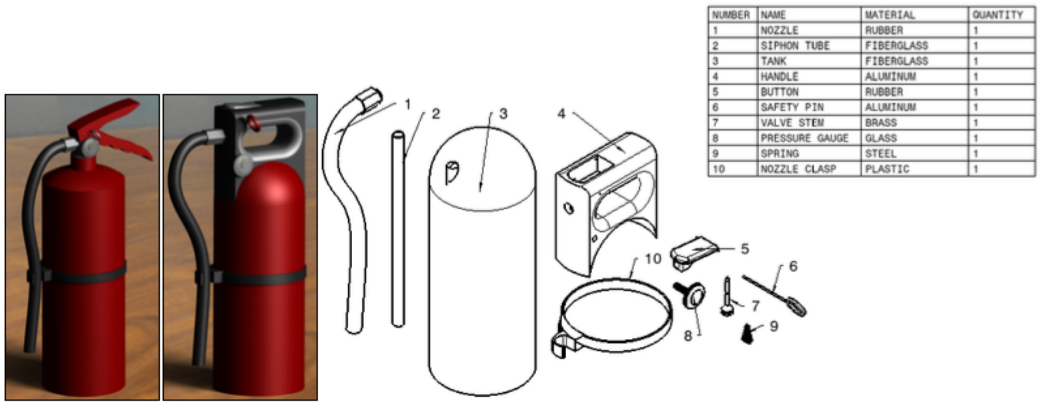
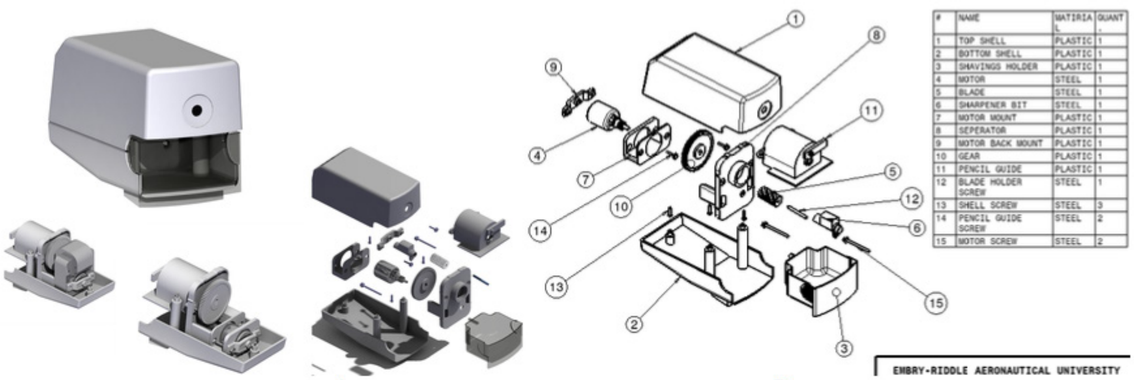


NUMBER	NAME	MATERIAL	QUANTITY
1	NOZZLE	RUBBER	1
2	SIPHON TUBE	FIBERGLASS	1
3	TANK	FIBERGLASS	1
4	HANDLE	ALUMINUM	1
5	BUTTON	RUBBER	1
6	SAFETY PIN	ALUMINUM	1
7	VALVE STEM	BRASS	1
8	PRESSURE GAUGE	GLASS	1
9	SPRING	STEEL	1
10	NOZZLE CLASP	PLASTIC	1

A B C

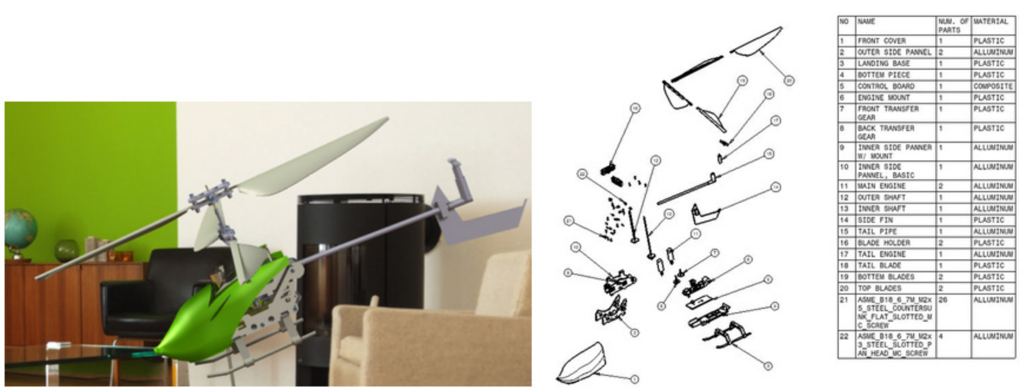
Figure 4. A: Original rendered fire extinguisher, B: Redesigned fire extinguisher with new handle design, C: Exploded view of the redesigned fire extinguisher from 2012.



#	NAME	MATIRIAL	QUANT.
1	TOP SHELL	PLASTIC	1
2	BOTTOM SHELL	PLASTIC	1
3	SHAVINGS HOLDER	PLASTIC	1
4	MOTOR	STEEL	1
5	BLADE	STEEL	1
6	SHARPENER BIT	STEEL	1
7	MOTOR MOUNT	PLASTIC	1
8	SEPERATOR	PLASTIC	1
9	MOTOR BACK MOUNT	PLASTIC	1
10	GEAR	PLASTIC	1
11	PENCIL GUIDE	PLASTIC	1
12	BLADE HOLDER SCREW	STEEL	1
13	SHELL SCREW	STEEL	3
14	PENCIL GUIDE SCREW	STEEL	2
15	MOTOR SCREW	STEEL	2

A B

Figure 5. A: Rendered pencil sharpener with lighter and cheaper motor design, B: Exploded view of the pencil sharpener from 2013.



NO	NAME	NUM. OF PARTS	MATERIAL
1	FRONT COVER	1	PLASTIC
2	OUTER SIDE PANNEL	2	ALLUMINUM
3	LANDING BASE	1	PLASTIC
4	BOTTEM PIECE	1	PLASTIC
5	CONTROL BOARD	1	COMPOSITE
6	ENGINE MOUNT	1	PLASTIC
7	FRONT TRANSFER GEAR	1	PLASTIC
8	BACK TRANSFER GEAR	1	PLASTIC
9	INNER SIDE PANNER W/ MOUNT	1	ALLUMINUM
10	INNER SIDE PANNEL, BASIC	1	ALLUMINUM
11	MAIN ENGINE	2	ALLUMINUM
12	OUTER SHAFT	1	ALLUMINUM
13	INNER SHAFT	1	ALLUMINUM
14	SIDE FIN	1	PLASTIC
15	TAIL PIPE	1	ALLUMINUM
16	BLADE HOLDER	2	PLASTIC
17	TAIL ENGINE	1	ALLUMINUM
18	TAIL BLADE	1	PLASTIC
19	BOTTEM BLADES	2	PLASTIC
20	TOP BLADES	2	PLASTIC
21	ASME_B18_6_7M_M2x5_STEEL_COUNTERSUNK_FLAT_SLOTTED_MC_SCREW	26	ALLUMINUM
22	ASME_B18_6_7M_M2x3_STEEL_SLOTTED_PAN_HEAD_MC_SCREW	4	ALLUMINUM

A B

Figure 6. A: Rendered RC-helicopter with USB port and charging indicator, B: Exploded view of RC-helicopter from 2014.

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Assessment Results

An anonymous student satisfaction survey was implemented at the end of each semester to collect students' feedback regarding the team project from spring 2011 through spring 2014. On average, over 50% of students completed the survey each semester. Final project engagement was analyzed as shown in Table 4.

Table 4
Students' final project satisfaction ratings.

Question	Semester	n	Strongly disagree (%)	Agree (%)	Strongly agree (%)
Overall I like the sustainable design project	Spring 2011	15	7	47	47
	Fall 2011	27	4	48	48
	Spring 2012	37	11	62	27
	Fall 2012	67	36	48	16
	Spring 2013	45	13	69	18
	Fall 2013	24	11	75	13
	Spring 2014	15	0	67	33
I like to work on team-based project	Fall 2012	67	19	59	23
	Spring 2013	45	13	47	40
	Fall 2013	24	8	54	38
	Spring 2014	16	0	31	69
My real-world problem solving, creative thinking and innovation, communication, and teamwork skills were improved	Fall 2012	68	19	38	43
	Spring 2013	45	7	20	73
	Fall 2013	24	4	42	54
	Spring 2014	16	6	13	81

Note: Percentages are rounded to the nearest whole number.

In Table 4, from the first question, we can see that over 83% of the students liked the sustainable design project; this rate increased to 100% in spring 2014. In the second question, over 81% of students preferred teamwork and this rate increased to 100% in spring 2014. In the third question, the majority confirmed that the final project helped them improve their real-world problem solving, creative thinking and innovation, communication, and teamwork skills, and this rate has been increased from 80% in fall 2012 to 94% in spring 2014.

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More constraints were added in fall 2012 in the report section by asking students to follow a template to complete the report. Students also needed to submit two different sets of designs. One is based on the product which is existing in today's market, and the other is their improved model which can involve either new technology, or a more user-friendly design that incorporates a sustainable design idea into their project. However, after adding more workload to the final project, the students' satisfaction of the final project dropped significantly in Table 4 in fall 2012. They enjoyed the design process better than it's documentation. In addition, a proportion of the students did not appreciate incorporating sustainable/green solutions into the project. In the following semesters, project starting date has been continuously moved toward the beginning of the semester to give students more time to define their topic, choose partners, and complete their project work. A revised report template and sample reports were also provided to the students to reduce their workload considering the limited project time and other course load during the semester.

Some students' responses to the satisfaction of the project are shown as follows:

- I enjoyed the fact that we got to choose our own topic for the final project. I enjoyed choosing something that was interesting to me but that was also challenging.
- It was cool to work with new people and build something new.
- I liked it, thought it was interesting.
- The final project was great!
- More time so that students can create more complex products.
- I think the final project was the best part of the class. I wish that we could make our own design and it doesn't require to be eco-friendly. Not all students like eco-friendly products.
- The report asks for way too much. The CATIA project itself should be all.
- Allow for the option of individual or groups because some people would always rely on their teammates to do all the work.
- I rather enjoyed the final project because I was forced to learn different aspects of CATIA that weren't covered in class. This experience will be less likely to be forgotten because of the need to learn it.

Students rated the final project highly as an opportunity to understand an engineering design process. They enjoyed designing their own product, working with different classmates, and challenging themselves. They believed that they learned more from the final project by exploring tools, which were not covered in class time, teaching themselves the communication skills, working as a team, enhancing their presentation skills. The

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main complaint was the limited time assigned to the project. Since there were only three weeks left for the project, they felt they could do much better if more time could be assigned. Based on student feedback, starting in spring 2012, the project time was extended to eight weeks long. Students were also required to submit periodic progress report, an individual logbook, and a final written report from each team to document their design ideas, process, timeline, cost analysis, and research findings.

There are many challenges to successfully integrate sustainable design into a freshmen-level course with design components. Some of the most significant challenges are listed below, which needs to be considered and an effective solution found to successfully incorporate the sustainable design concept.

- Communication problems in the team, which needs the instructor to pay attention and address as early as possible
- Picking an appropriate topic is challenging to the students
- Open-ended projects maybe overwhelming to some students who still like to follow the instructor's direction
- Time management is still a big issue to most of the students, especially freshmen
- Self-seeking solutions is frustrating to the students
- Students need to adjust to solve real-world complex problem rather than the simple homework problems
- Teamwork is still a challenge to most of the students, especially freshmen
- It is hard to balance the amount of constraints and the creativity level in the project requirements

A formal assessment was completed using ABET rubrics in Table 2 besides the students-satisfaction survey. Table 5 displays the results of the formal assessment from 2011 to 2014, specifically sustainability design. ABET assessment criterion (c) identifies the increased understanding of the sustainability design concept. Students are able to identify the problem and apply the sustainability concept to the final project design. This could be attributed partially to the author's instruction experience. As more sustainability related project examples are given in the class time as an introduction, students' understanding of sustainability has been increased over the years. Their reports documented the problem statement, research findings, and how to solve the social, environmental, and economic challenges in their final project design. However, since most of them are still freshmen or sophomores, their creativity and innovation was not well grounded into their data/findings to provide arguments for the feasibility of the idea. Beiler (2014) supported this finding in her study as well.

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ABET assessment criterion *(g)* indicates that students' communication and teamwork skills improved as the class developed. The peer evaluation and team evaluations are confidential, which offer them an opportunity to evaluate themselves, their teammates, and their classmates. From the peer evaluation, most of them were able to collaborate with their teammates to accomplish the project within the given time, and self-evaluation reflected their personal effort. Team evaluation is used to evaluate the other team's presentation performance based on the given rubric. From the comments they gave on the team evaluation, it showed that they valued the opportunity, and left candid and constructive comments to the other teams. Periodically there were team issues such as miscommunication, personality, workload imbalance, and capability deficiency. Previous research has shown that giving students the specific instruction and grounded rules in this critical skill is essential to the success of teamwork (Dawes, Fisher, & Mercer, 1992; Matusovich, Paretti, Motto, & Cross, 2012; Paretti et al., 2011; Shuman, Besterfield-Sacre, & McGourty, 2005). The increased proficiency of the communications skills over the years suggests that combining the use of rules and specific instruction is of mixed success.

ABET assessment criterion *(h)* evaluates student's application of sustainability in CATIA part and product design. Overall students are proficient in the application of the sustainability concept in CATIA design and this proficiency is increased over the years. Since this is a fundamental course, student's CATIA ability limited their achievement of the creative and innovative ideas to some extent, which is reflected in the higher proficiency (Excellent) in ABET *(c)* and lower proficiency (Excellent) in ABET *(h)*.

Table 5
Results of formal assessment applied to final project 2011-2014.

	Proficiency Level											
	Unsatisfactory				**Satisfactory**				**Excellent**			
ABET criteria	2011 (%)	2012 (%)	2013 (%)	2014 (%)	2011 (%)	2012 (%)	2013 (%)	2014 (%)	2011 (%)	2012 (%)	2013 (%)	2014 (%)
c	0	0	0	0	41	43	32	53	59	57	68	47
g	0	0	0	3	48	37	32	27	52	63	68	70
h	0	0	0	0	69	53	47	53	31	47	53	47

Conclusions

This paper has presented a transition from a guided individual project to a sustainable team project in a graphical communication course. The sustainable team project offered students an opportunity to learn the engineering design process while emphasizing environmental, economic, and social responsibility. It gave students opportunities to inquire into, collaborate on, design, assemble, and present their work, beyond those provided to

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previous classes. A questionnaire-based methodology was used to assess the success of the study. The assessment results indicate that student's enjoyment of the sustainable design project increased and their innovative thinking, communication, and teamwork skills were improved in the sustainable design project over three years data analysis. They were able to think outside the box and solve real-world problems, which enables them to solve company, country, even global challenges (Reid & Ferguson, 2011).

It is believed that by integrating sustainable design concepts into the final project students learned the importance of innovation and teamwork. They also learned engineering design that emphasized environmental, economic, and social responsibility. An important next step is to determine how the sustainable design project that emphasizes innovation and teamwork influences specific learning outcomes such as students' ability to master the material (Barron & Hulleman, 2006), deeper understanding of course topics, and student motivation and self-efficacy. Self-efficacy has been shown to be strongly linked to their motivation to succeed in the class (Hutchison, Follman, Sumpter & Bodner, 2006; Zimmerman, 2000). It has been found that students with high efficacy are more likely to undertake difficult tasks, work harder, and persist longer at the tasks than the students with low efficacy. Surveys should be given to the students when they finish upper-level courses to check the impact of the sustainable design project on their competence and ultimately their performance in other classes.

References

ABET Engineering Accreditation Commission (2013). Criteria for accrediting engineering programs: Effective for reviews during the 2014-2015 Accreditation Cycle (E001 3/13/14). Baltimore, MD: ABET.

ASEE Board of Directors. (1999) ASEE statement on sustainable development education. Retrieved May 15, 2015, at https://www.asee.org/about-us/the-organization/our-board-of-directors/asee-board-of-directors-statements/sustainable-development-education

Autodesk. (2012) Autodesk sustainability workshop. Retrieved May 15, 2015, at https://www.youtube.com/user/AutodeskEcoWorkshop.

Barrera-Roldan, A., & Saldivar-Valdes, A. (2002) Proposal and application of a sustainable development

index. Ecol. Indic. 2, 251-256.

Barron, K. E., & Hulleman, C.S. (2006). Is there a formula to help understand and improve student motivation? In Saville, B.K., Zinn, T.E., Meyers, S.A. & Stowell, J.R. (Eds.), Essays from Excellence in Teaching, 2006 (chap. 8).

Beiler, M. R. O. (2014). Integrating innovation and entrepreneurship principles into the civil engineering curriculum. *Journal of Professional Issues in Engineering Education & Practice*. 1052-3928/04014014(8).

Bielefeldt, A.R., Jones, S.A., Price, J.M., Grahame, K.S., & Gillen, A. (2016). Impacts of sustainability education on the attitudes of engineering students. *Proceedings of the American Society for Engineering Education (ASEE) Annual Conference and Exposition*, New Orleans, LA.

Bloom, B. S. (1956). Taxonomy of educational objectives: The classification of educational goals. *In B.S. Bloom (Ed.) Taxonomy of Educational Objectives Book 1: Cognitive Domain* (pp. 201-207). Longman, NY: Susan Fauer Company, Inc.

ISSN: 1949-9167

Byers, T. Seelig, T., Sheppard, S., & Weilerstein, P. (2013). Entrepreneurship: Its role in engineering education. *Bridge National Academy of Engineering*. 4(2), 25-40.

Dawes, L., Fisher, E., & Mercer, N. (1992). The quality of talk at the computer, *Language and Learning*, V. 22, No. 3, pp. 22-25.

Doyle, T. E., Baetz, B. W., & Lopes B. (2009). First-year engineering bicycle dissection as an introduction to sustainable design, *Proceedings of the Canadian Engineering Education Association*.

Farris, J., & Lane, P. (2005). Reality learning: Teaching higher on bloom's taxonomy. *Proceedings of the American Society for Engineering Education (ASEE) Annual Conference and Exposition*, Portland, OR.

Hertzog, P., & Swart, A. J. (2015). The use of an innovative jig to stimulate awareness of sustainable technologies among freshman engineering students. *Sustainability*, 2015, 7(7), 9100-9117.

Hutchison, M., Follman, D., Sumpter, M., & Bodner, G., (2006). Factors influencing the self-efficacy beliefs of first-year engineering students. *Journal of Engineering Education*, 96(1), 39-47.

Matusovich, H., Paretti, M.C., Motto, A., & Cross, K. (2012). Understanding faculty and student beliefs about teamwork & communication skills. *Proceedings of American Society for Engineering Education (ASEE) Annual Conference and Exposition*, San Antonio, TX.

National Academy of Engineering. (2004). The engineer of 2020. Washington, DC: National Academies Press.

Paretti, M.C., Layton, R., Laguette, S., & Speegle, G. (2011). Managing and mentoring capstone design teams: considerations and practices for faculty. *International Journal of Engineering Education*, 2011. 27(6): p. 1192-1205.

Paudel, A. M., & Fraser, J. M. (2013), Teaching sustainability in an engineering graphics class with solid modeling tool. *Proceedings of the American Society for Engineering Education Annual Conference*, Atlanta, GA.

Pfluger, C., & Schulte Graham, K. (2014). Introducing sustainability into engineering design: A first year course. *Proceedings of the American Society for Engineering Education Annual Conference*, Indianapolis, IN.

Price, M. J., & Aidoo, J. (2013). Introducing sustainable design principles in freshman civil engineeringdesign, *Proceedings of the American Society for Engineering Education Annual Conference*, Atlanta, GA.

Reid, K., & Ferguson, D. (2011). Enhancing the entrepreneurial mindset of freshman engineers. *Proceedings of American Society for Engineering Education (ASEE) Annual Conference and Exposition*, Washington, DC.

Shuman, L.J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET "professional skills" - Can they be taught? Can they be assessed? *Journal of Engineering Education*, 94(1): p. 41-56.

United Nations. (2002a) Education for sustainability – from Rio to Johannesburg: Lessons learnt from a decade of commitment, *World Summit on Sustainable Development*, Johannesburg, South Arica, August 26-September 4.

United Nations. (2002b) Resolution 57/254: United Nations decade of education for sustainable development. *United Nations 78th Plenary Meeting*, New York, December 20.

Weber, N. R., Strobel, J., Dyehouse, M. A., Harris, C., David, R., Fang, J., & Hua, I. (2014) First-year students' environmental awareness and understanding of environmental sustainability through a life cycle assessment module. *Journal of Engineering Educatio*n, 103, 154-181.

ISSN: 1949-9167

WECD (World Commission on Environment, Development, the ''Brundtland Commission''). (1987) Our Common Future. Oxford: Oxford University Press.

Zimmerman, B. (2000) Self-efficacy: an essential motive to learn. *Contemporary Educational Psychology*, 25, 82-91.

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