Assessing Impact of Maker Space on Student Learning

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Rodney Boehm has joined the Engineering Academic and Student Affairs (EASA) team as an Industry Mentor with very broad experiences, including the creation of a telecommunications standard for the fiber optics industry that is still in use internationally over 25 years later, a wide variety of business experiences in an international company, and start up experience that have helped him hone his ability to quickly determine a direction and execute to it.

He is also formerly the Chief Operating Officer for GroundFORCE, a company that specializes in a unique patented construction technology. His extensive experience in running sales, marketing, manufacturing,

and large multi-national organizations was applied to introducing this new technology to the construction industry.

Formerly he was a Senior Vice President of Fujitsu Network Communications, headquartered in Richardson, Texas. With over 30 years of experience in telecommunications, Rodney was responsible for developing partnerships with leading network technology providers and driving marketing efforts for optical, access and data products developed by Fujitsu. Along with Yau Chow Ching, Rodney conceived (and wrote the standards for), the SONET (Synchronous Optical Network) architecture, which served as the base for today's North American telephone network. Rodney was Chairman of the T1X1 Technical Sub-Committee (the organization responsible for SONET standardization) from 1990 through 1994. He has been active in SONET's National and International Standardization since 1985. In addition, Rodney has published numerous papers and presentations on SONET.

Rodney began his career with Fujitsu Network Communications in 1989 as the Director of Strategic Planning. He also held the positions of Director of Transport Product Planning, Vice President of Business Management, Senior Vice President of Sales Management, Senior Vice President of Manufacturing, and Senior Vice President of Business Development. Before joining Fujitsu, Rodney worked for Bell Laboratories, Bellcore (now Telcordia), and Rockwell International. He earned both his bachelor's and master's degrees in electrical engineering at Texas A&M University.

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Prasad Enjeti (enjeti@tamu.edu) is a member of Texas A&M University faculty since 1988 and is widely acknowledged to be a distinguished teacher, scholar and researcher. He currently holds the TI-Professorship in Analog Engineering and Associate Dean for Academic Affairs in the College of Engineering. His research emphasis on industry-based issues, solved within an academic context, has attracted significant external funding. Up until now, he has graduated 29 PhD students and 11 of them hold academic positions in leading Universities in the world. He along with his students have received numerous best paper awards from the IEEE Industry Applications and Power Electronics Society. His primary research interests are in advancing power electronic converter designs to address complex power management issues such as: active harmonic filtering, adjustable speed motor drives, wind and solar energy systems and designing high temperature power conversion systems with wide band-gap semiconductor devices. In 2000 he was named an IEEE Fellow and in May 2004 received a distinguished achievement award for teaching from Texas A&M University. He is the recipient of IEEE PELS R. David Middlebrook Technical Achievement Award from the IEEE Power Electronics Society. 2012.

Assessing Impact of Makerspaces on Student Learning

Abstract

In today's global market, advances in manufacturing processes and technology in general have transformed innovation and allow industries to prototype new product ideas more rapidly and less expensively than ever before. As a result, product development processes are changing drastically; engineering graduates will benefit by further developing their skills for innovation and project/process development. At the national level, The Innovative and Entrepreneurial University Report[1] states that while the United States remains the global leader in innovation and entrepreneurship, there is increasing global competition. To address this, literature [2-7] shows that universities across the country have recognized the need for maker spaces and have invested resources to develop such facilities in order to provide engineering undergraduates with opportunities for experiential and project-based learning to better promote creativity and innovative skills. Maker spaces vary in size, resources, programs, and targeted population and they represent a significant development in engineering education. Some are located in places such as libraries[7] with a focus to attract partnerships form the local community. In this large public institution, the college of engineering established a 20,000 square-foot makerspace in 2013 solely dedicated to engineering undergraduates. The facility offers students access to: 1) fabrication equipment such as 3D Printers, CNC and manual lathes and mills, and electronic circuit board fabrication; 2) microcontrollers and sensors; 3) collaborative spaces which include studio, conference and meeting rooms; 4) wide range of software tools to support engineering analysis, and 5) experienced professional staff able to guide student's use of equipment and tools. Students utilize facility resources for curricular activities such as capstone design projects, multidisciplinary project based elective courses, and extra-curricular programs such as design competitions. Since 2013, the number of students requesting access to the facility has increased significantly, with more than 1500 students registered for 2015 fall. To provide students with specific skills and knowledge, often related to the capacities of the makerspace, the college launched a series of pop up classes in fall 2015. The pop up class program has been very successful with more than 750 students registered for 2015 fall semester. This study will assess how utilization of the facility influences student development. While anecdotal evidence suggests facility resources empower participants to pursue more innovative designs, this study is the first systematic assessment on campus of student self-reported confidence and motivation to pursue certain tasks such as engineering design. Findings will contribute to the growing body of knowledge about maker spaces and their influences on engineering education.

Introduction

In today's global market, advances in manufacturing processes and technology in general have transformed innovation and allow industries to test new product ideas more rapidly and less expensively than ever before. As a result, traditional processes of developing and testing new products are changing drastically and engineering graduates entering the workforce will benefit by possessing skills in creativity and innovation. At the national level, The Innovative and Entrepreneurial University Report[1] states that while the United States remains the global leader in innovation and entrepreneurship, there is increasing global competition. One approach to maintain our leadership position is to establish maker spaces as physical learning environments where students can generate and fabricate design ideas rapidly. The assumption is that creation of maker spaces will support student development with respect to engineering design, innovation, and entrepreneurship.

As an example of the trend toward educational maker spaces, a recent review on university maker spaces[3] investigated maker spaces at 127 institutions ranked as the top 100 (multiple institutions for same ranking) in the 2014 US News and World's Report. In this report, 35 of these schools offer 40 significantly different makerspaces. Some are offered within colleges while others are open to students across campus or even the community. In addition, the management of the facilities varies since some are faculty or staff run while others are student-run. Finally, there is a wide range of resources offered at these facilities but in general many offer 3D printers, laser cutters, wood and metal shops, and collaborative spaces.

While many universities are considering offering makerspaces, influences of makerspaces with respect to professional growth of students is still not well understood. In an attempt to partially fill this gap, the study reported in this paper will address the following research questions:

- RQ1: How frequently do students use the facility and what types of resources do they use?
- RQ2: What is the perceived impact on their professional and personal growth because of them having access to the facility?
- RQ3: What is the level of self-confidence of students who use the facility in the skills that facility was developed to support?
- RQ4: Are there any differences based on gender and ethnicity?

In this study, we utilize an assessment instrument[4] used by another institution to collect data and compare findings. While the two maker spaces have many similarities and are housed within large public engineering schools, a professional staff runs one while the other is student run. The authors of this study believe the comparison and findings will add to the broader knowledge of the impact of maker spaces.

Facility Description

The facility is a 20,000-square-foot makerspace, which opened in 2013 to primarily support senior capstone design and multidisciplinary teams across engineering departments in the college of engineering. The facility includes collaborative spaces to support team projects, access to fabrication resources and materials, and programs to promote effective use of facility resources to support college goals for innovative and entrepreneurial minded engineering graduates. The facility consists of three main areas: design studio, fabrication center, and technology center.

The *Design Studio* is the main collaborative space to support students working on team projects. This area contains workbenches, both reserved for team long-term use and open access, lockers, and stations. Lockers, lockable tubs and storage rooms are available for teams to store their projects. Stations are dispersed throughout the *Design Studio* with tools or equipment most often used to make them more accessible to a large number of students. Stations have weights and measures, electronic measurement equipment, soldering, hand tools, sewing, and 3D printers (Fig 1.). In addition, the *Design Studio* offers a large open area to accommodate up to 75 students for presentations.

The *Fabrication Center,* Fig 2, is a 4,500 ft^2 space that includes equipment for metalworking, machining, welding, paint booth, woodworking, commercial 3D printers, CNC mill & lathe, laser cutting, foam cutting, PCB milling and composite manufacturing capabilities. Access to this area is strictly controlled for safety. Only students with proper safety training have access.

The *Technology Center* area consists of the computing center which maintains 12 high-end computer workstations, a digital media room for video and audio production, 3D scanning capabilities, two conference rooms with video conferencing equipment to support interactions with industry sponsors, and the Checkout Equipment and Help Center which is open sixteen hours a day Monday thru Friday.

To promote effective student use of these facilities and offer opportunities to acquire knowledge and skills, the college has launched several programs. These include signature programs such as pop up classes, a 48-hour design challenge, a video contest, hosting seven student organizations, six competition teams, and four summer camps.

Two full time professional staff maintain and manage the facility while twenty-five student technicians are available extended hours and over the weekend to support students. The facility is open Monday thru Friday 8 AM – 12 AM. On the weekends, it is open 2 PM– 12 AM.

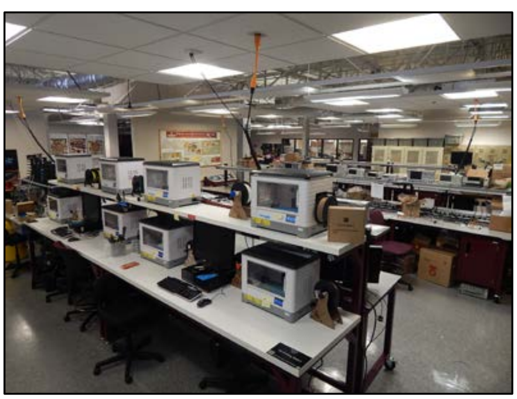

Figure 1- 3D Printer Stations

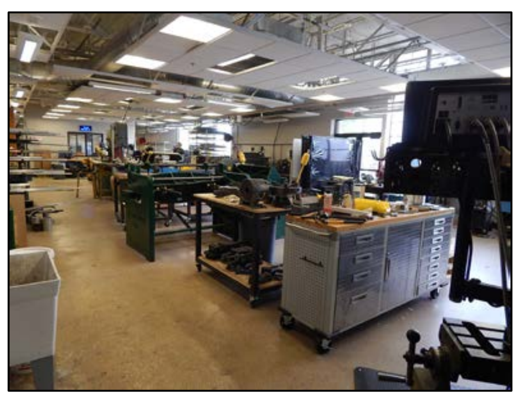

Figure 2- Fabrication Center

Survey Methodology

The authors used a modified version of the survey described in [4]. Modifications were made because some of the questions in the original survey were specific to the facility presented in [4].

Based on records kept by the staff of the maker space, the most frequent users of the space were students enrolled in capstone design courses. Therefore, the authors decided to focus on students enrolled in the capstone design courses in the departments of electrical (ECEN) and mechanical (MEEN) engineering because they are the ones who most heavily use the facility. During 2016 spring semester, 260 students in these two courses were invited to participate in this study. 46.7% of electrical and 41% of mechanical engineering students enrolled in capstone design completed the survey. Survey participants include 78 ECEN students (10% females and 16% Hispanic/Black) enrolled in ECEN 403 & 404 and 45 MEEN seniors (18% female and 13% Hispanic/Black) enrolled in MEEN 402. This paper will present the data collected from students enrolled in the capstone design courses.

Research Findings

Survey Respondent Demographics

Survey participants include 78 ECEN students (10% females and 16% Hispanic/Black) enrolled in ECEN 403 & 404 and 45 MEEN seniors (18% female and 13% Hispanic/Black) enrolled in MEEN 402.

Facility Utilization

RQ1: How frequently do students use the facility and what resources to they use?

As shown in Fig. 3, about 25% of MEEN capstone students use the facility between 5-10 hours compared to 55% of ECEN students. It is worthwhile to note that another 25% of ECEN students report using the facility between 10-15 hours per week. This can be explained by the fact that ECEN students use the facility for more class meetings than MEEN students.

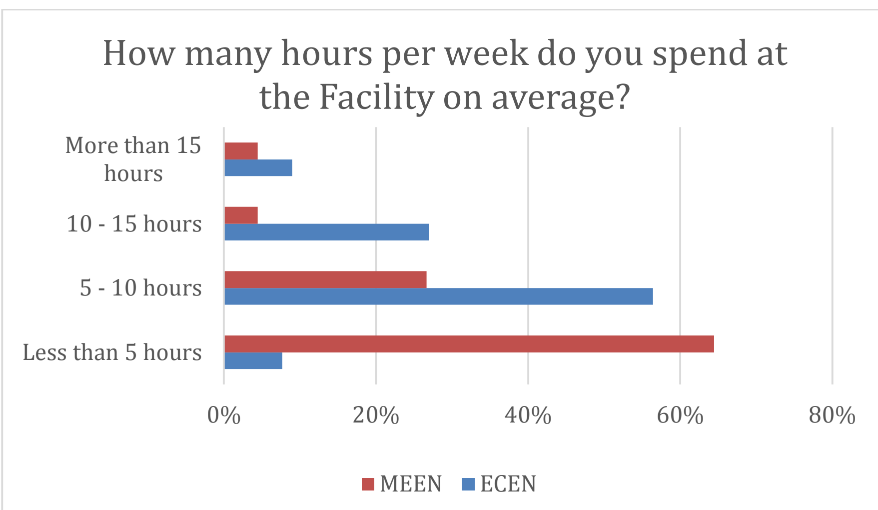

Figure 3. Hours per Week Spent at Facility

Next, participants were asked: “What percentage of their time was spent using different resources?” The total for each respondent is expected to be 100%. Then, the individual data was used to calculate the "percentage average" for the most commonly used resources, shown in Fig 4.

Based on the data, on average, the ECEN participants spent about 50% of their time at the facility in utilizing the collaborative space and about 30% of their time attending a class. In comparison, on average, MEEN participants spent about 25% using the collaborative space, 25% attending class and about 15% using the fabrication lab and 15% other areas of the facility.

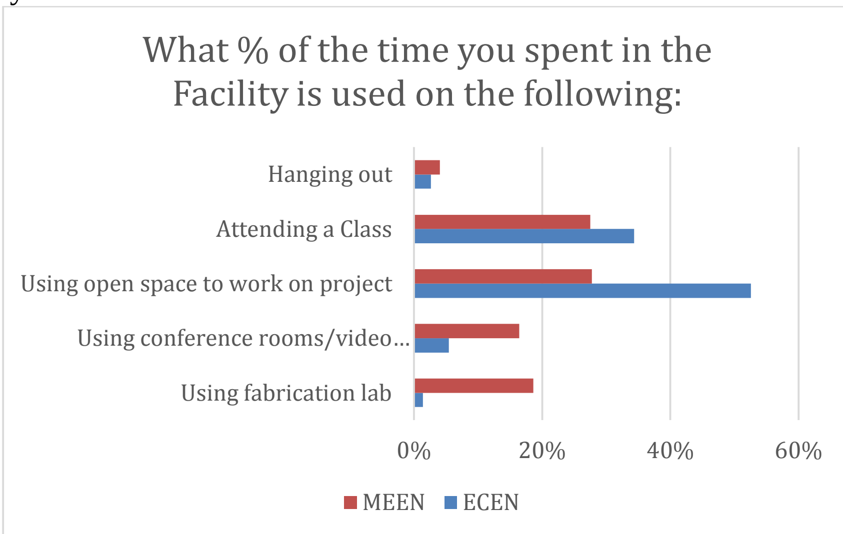

Figure 4.Activity that Student Engages In While at Facility

In addition, participants were asked about the types of specific resources used in the facility, as shown in Fig 5. The resource used most frequently by both groups is conference rooms. As expected, more than 70% of ECEN students use electronic board fabrication. Similarly, MEEN students use the resources closely associated with fabricating mechanical components: 3D printers, lathes, mills, and laser cutter.

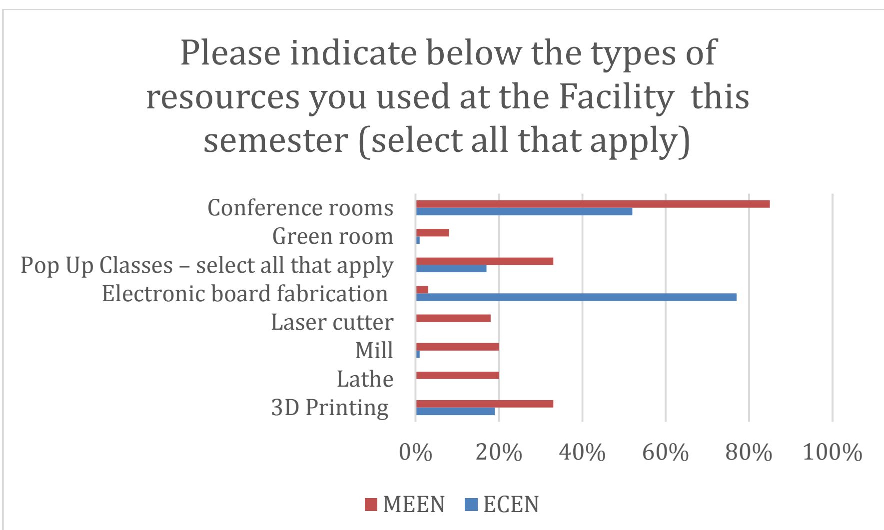

Figure 5.Usage of Makerspace Resources

Impact on Professional Achievements
RQ2: What is the perceived impact on student professional and personal growth because of them having access to the facility?

Survey respondents were asked a series of questions that used a 10-point Likert Scale (1-very negative impact, 10-very positive impact), Fig. 5 and 6. While 58% of ECEN students report “some” to “very” positive impact (8-10) on professional development, only 30% of MEEN students report similar impact (8-10). 37% of MEEN students report no measurable impact.

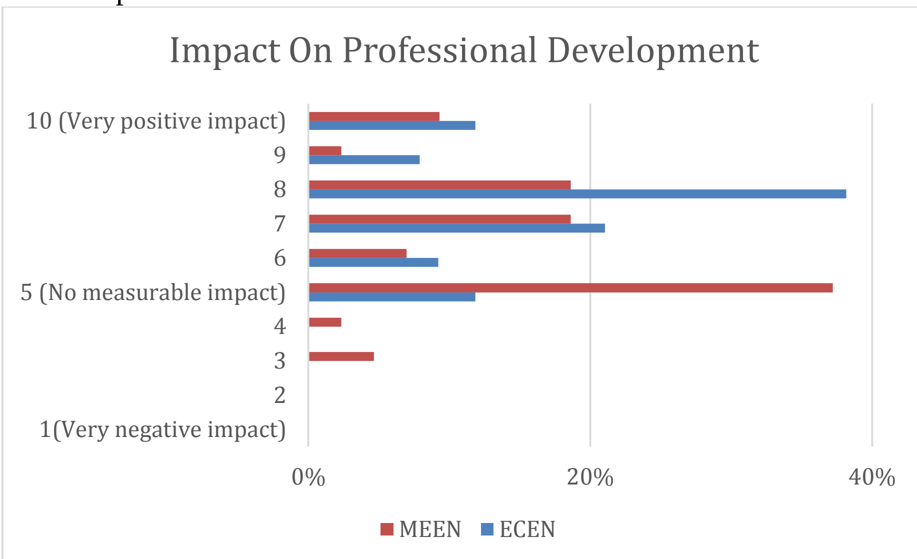

Figure 6. Impact on Professional Development

Similarly, 49% of ECEN students report positive impact on personal growth (8-10) while 25% of MEEN students report similar impact. Again, it is worth noting that 35% of MEEN students report no measurable impact on their personal growth.

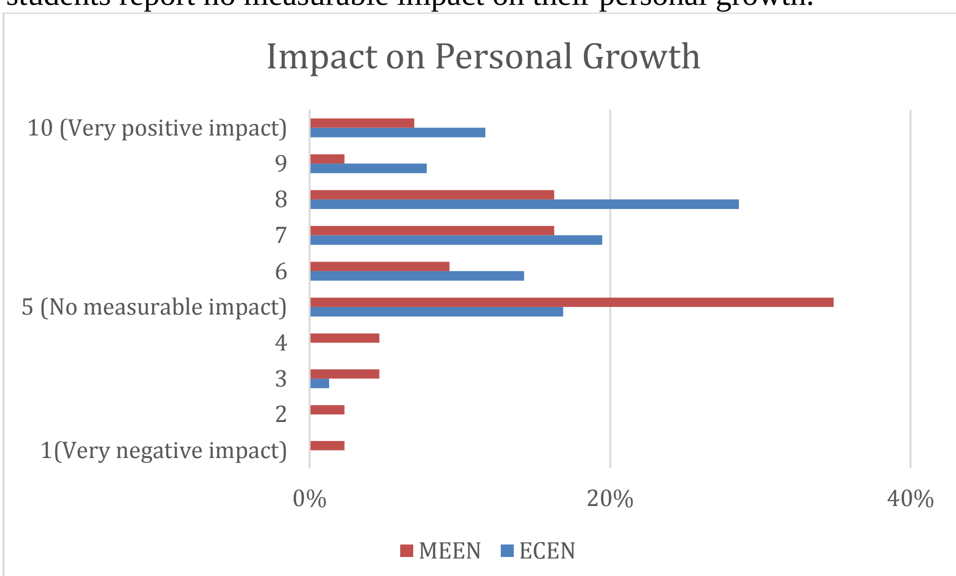

Figure 7. Impact on Personal Growth

Next, they were asked about impact on specific areas associated with professional and personal growth. Per Table 1, more than 50% of ECEN students have identified six areas of impact: friends, outlook in engineering, skills in design, time management, communication and teamwork. 47% of ECEN students report impact on GPA. In comparison, there is only one area where more than 50% of the MEEN participants (63%) report impact. There are six additional areas that more than 30% of participants identified as impactful: GPA, outlook in engineering, skills in design and manufacturing, time management, communication.

Table 1. Impact on Development with Respect to Various Professional and Personal Areas

	ECEN	**MEEN**
GPA	47%	32%
Employment	9%	5%
Friends	53%	24%
Outlook on engineering	58%	37%
Skill in design	76%	42%
Skill in manufacturing	36%	42%
Leadership	27%	16%
Financial management skills	4%	3%
Time management	65%	39%
Integrity and ethics	18%	11%
Safety	34%	26%
Community service and outreach	1%	0%
Communication	59%	39%
Teamwork	85%	63%

It is worth noting that the both groups agree on skills in design, time management, and teamwork as the most impacted.

Degree of Confidence

RQ3: What is the level of self-confidence and motivation of students who use the facility in the skills that the facility was developed to support?

Students were also asked to rate their degree of confidence to perform design tasks (Q1 to Q9):

- Q1: Conduct engineering design
- Q2: Identify a design need
- Q3: Research a design need
- Q4: Develop design solutions
- Q5: Select the best possible design
- Q6: Construct a prototype
- Q7: Evaluate and test a design
- Q8: Communicate a design
- Q9: Redesign.

The scale ranged from 0 (cannot do at all) through 50 (moderately can do) to 100 (highly certain can do). Figs. 8 and 9 show survey data from the two capstone groups. It is interesting to note that more than 60% of ECEN students report confident (80 to 100) for all design tasks. In comparison, 65% of MEEN students report similar confidence. In addition, while very few ECEN students report below 30, there are more MEEN students indicating lack of confidence to perform these tasks.

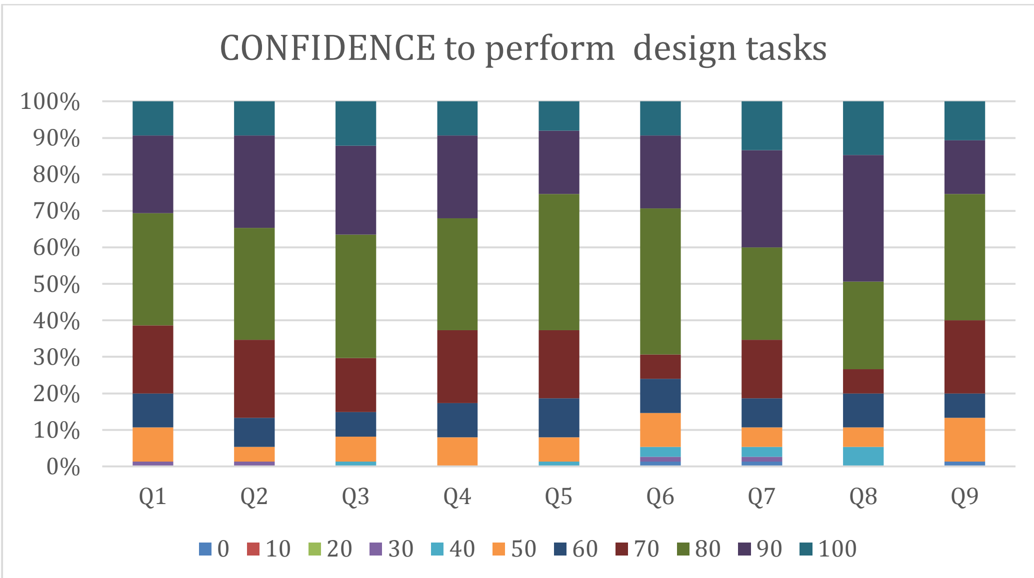

Figure 8. Confidence to Perform Design Tasks - ECEN Students

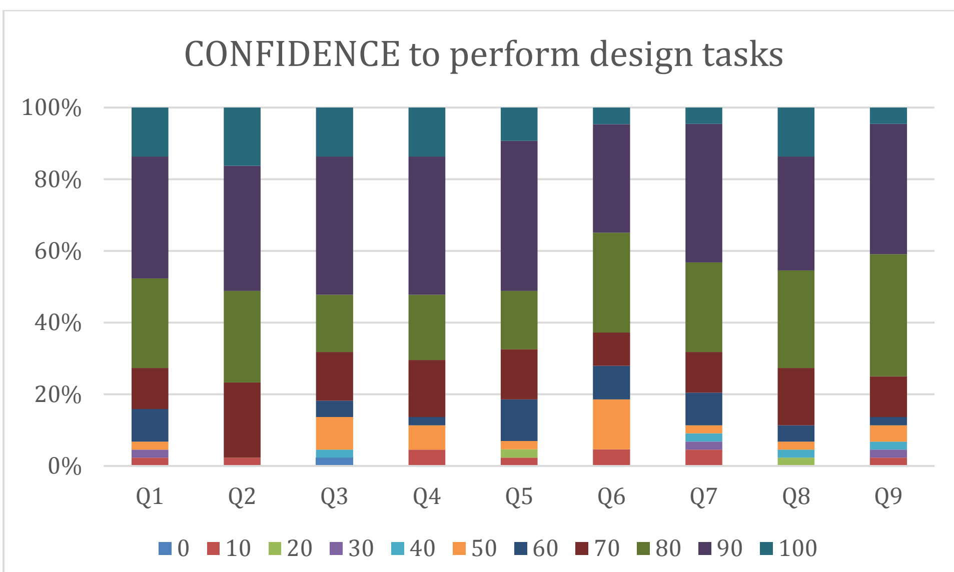

Figure 9. Confidence to Perform Design Tasks - MEEN Students

Students were also asked "Rate how MOTIVATED you would be to perform the following tasks by recording a number from 0 to 100. (0 = not motivated; 50 =

moderately motivated; 100 = highly motivated). About 50% of ECEN and MEEN participants report they are motivated to perform all tasks associated with design and prototypes (see Figs. 10 and 11). However, it is interesting to see again more MEEN students reporting lack of motivation to perform some of these design tasks.

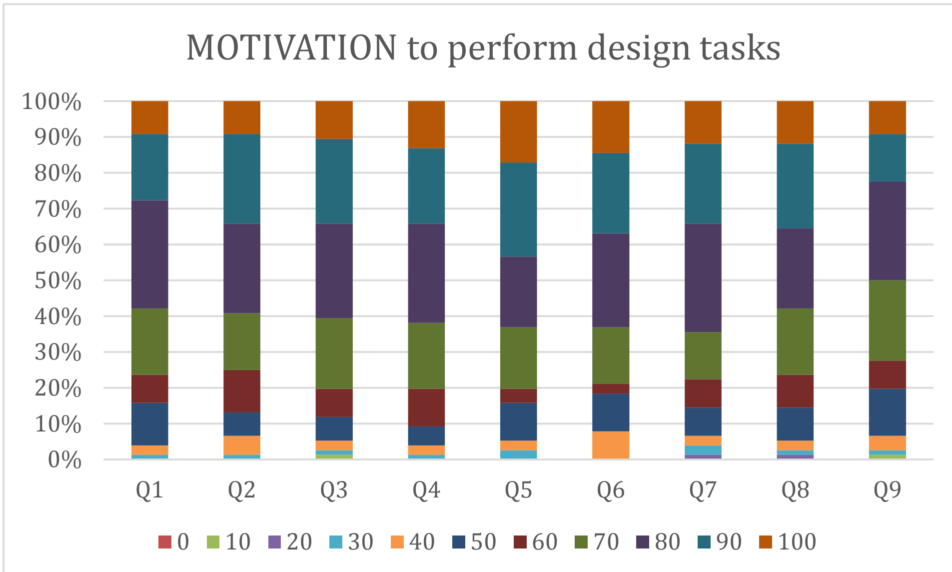

Figure 10. Motivation to Perform Design Tasks - ECEN Students

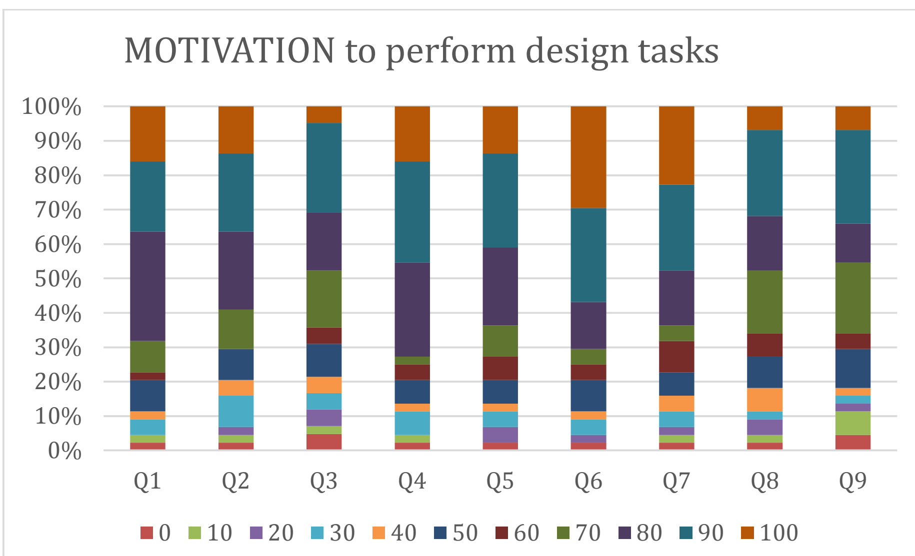

Figure 11. Motivation to Perform Design Tasks - MEEN Students

Facility Achievements

Finally, survey participants were asked to rank on a scale of 1-5, (5 being mostly and 1 being not at all), to what extent "do you feel that the facility achieved its goals". Table 2, shows reported mean values for ECEN and MEEN students. Overall, the data indicate that survey participants think the facility is achieving its goals at various levels with "encourage collaboration" and "excite students for career involving creativity, design, innovation and invention" ranked the highest marks by both groups.

Table 2. Facility Achievements		
Question	**Mean - ECEN**	**Mean - MEEN**
Access to state-of-the-art prototyping technologies	3.88	3.77
A cultural hub	3.47	2.74
Foster design in classwork	3.97	3.40
Foster design in extracurricular activities	3.69	2.88
Encourage collaboration	4.13	3.51
Welcoming environment for all types of projects	4.12	3.60
Excite students for careers involving creativity, design, innovation, and invention	3.99	3.51
Enable students to tackle open-ended, real world challenges	4.01	3.53
Serve as an exhibit and tour space	3.84	3.42

Gender and Ethnicity

RQ4: Are there any differences based on gender and ethnicity?

The data was also analyzed based on gender and ethnicity. Preliminary data show that females report higher impact of the facility on their GPA, friends, outlook on engineering, skill in design, communication and teamwork. Similarly, Hispanics report higher impact of the facility on GPA, outlook on engineering, communication and teamwork. Furthermore, both females and Hispanics report lower levels of confidence for pursuing design tasks.

Conclusion

Maker spaces are being established in educational institutions to promote student development in areas such as engineering design, innovation, and entrepreneurship. More information about use of a recently established maker space at one institution was sought to ascertain how the space was being used and how it was influencing student development. Survey results show that it is influencing student development with several elements in engineering design processes, but differences between MEEN and ECEN students suggest that more in-depth understanding of how usage of the space influence student development with respect to these elements is needed.

This study was completed under IRB approval (IRB2015-0672D).

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