122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #13479

No Lab? No Shop? No Problem: Intentional Design of a First Year Engineering Learning Center with Enlightening Outcomes

Jennifer Ocif Love, Northeastern University

Jennifer Love, Susan Freeman, Beverly Kris Jaeger-Helton, and Richard Whalen are members of Northeastern University's Gateway Team, a selected group of faculty expressly devoted to the First-Year Engineering Program. The focus of this team is to provide a consistent, comprehensive, and constructive educational experience in engineering that endorses the student-centered and professionally-oriented mission of Northeastern University.

Dr. Susan F Freeman, Northeastern University

Susan Freeman, is a member of Northeastern University's Gateway Team, a group of teaching faculty expressly devoted to the first-year Engineering Program at Northeastern University. The focus of this team is on providing a consistent, comprehensive, and constructive educational experience that endorses the student-centered, professional and practice-oriented mission of Northeastern University.

Dr. B. Kris Jaeger, Northeastern University

Beverly Kris Jaeger, PhD is on the full-time faculty in the Department of Mechanical and Industrial Engineering at Northeastern University teaching Simulation Modeling and Analysis, Facilities Planning, and Human-Machine Systems. She has also been an active member of Northeastern's Gateway Team, a select group of teaching faculty expressly devoted to the first-year Engineering Program at NU. She also serves as a Technical Faculty Advisor for Senior Capstone Design and graduate-level Challenge Projects in Northeastern's Gordon Engineering Leadership Program. Dr. Jaeger has been the recipient of numerous awards in engineering education for both teaching and mentoring and has been involved in several engineering educational research initiatives through ASEE and beyond.

Dr. Richard Whalen, Northeastern University

Dr. Richard Whalen is a Teaching Professor at Northeastern University in Boston, MA and a core member of the Engineering Gateway Team. The focus of this team is on providing a reliable, wide-ranging, and constructive educational experience that endorses the student-centered and professionally-oriented mission of the University. He also teaches specialty courses in the Department of Mechanical and Industrial Engineering at Northeastern and has published and presented papers on approaches and techniques in engineering education. He has won multiple Outstanding Teaching Awards at Northeastern and numerous Best Paper and Best Presentation Awards with fellow Gateway coauthors at ASEE.

No Lab? No Shop? No Problem: Intentional Design of a First Year Engineering Learning Center with Enlightening Outcomes

Abstract

In Fall 2013, the First Year Engineering Program at Northeastern University opened a new 1600 ft^2 Learning Center that was designed to provide first-year engineering students with: (1) a collaborative teaching and learning space that fosters communication, teamwork, applied active learning and self-directed learning, (2) a dedicated workshop setting with accessible hand tools to facilitate their hands-on design projects, (3) a central office and meeting location in which to engage with their first-year instructors for office hours, extra help and advising, and (4) an academic resource and community center including a bank of computers and 3D printers to support their first-year engineering courses. In order to track students' activities in the new Engineering Learning Center and their perceptions of the Center's effectiveness with respect to their engineering coursework, qualitative and quantitative data regarding the Center's first academic year of operation were collected from students who were currently enrolled in at least one first-year engineering course. These measures included online surveys, observations by faculty, and recorded headcount data of students using the Center.

Results indicate that over 80% of the responding students who visited the Learning Center at least once during the Fall 2013, Spring 2014, or Fall 2014 semesters believed that the Center and its resources were "important" or "essential" to their academic success in their first-year engineering course(s). In addition, the majority of students' activities in the Learning Center that supported their engineering coursework included working on team design projects, using the network computers, attending a special first-year class, using the 3D printers, using hand tools to build a project, using the space to meet with classmates, and getting help from teaching assistants and faculty members. Qualitative analyses revealed that students generally valued the resources in the Learning Center but remarked –not surprisingly– that the Center's actual operational space, which is only 700 ft^2 of the total 1600 ft^2, was too small to handle the high usage demand during certain weeks of the semester when various design projects were due across multiple course sections. One of the primary outcomes of this initiative was learning that the faculty and their educational objectives were generally aligned with the students' impressions and needs. At the same time, there were some areas of opportunity where this alignment could be improved and challenges could be pre-empted by defining the space to the students with clarity and intention.

The lessons learned from this initiative indicate that our college's Learning Center is being used as intended, and while it is small for the given population of over 700 first-year students, the original design elements and planning efforts have paid off. The research demonstrates that even with limited resources and space, one can create a centralized area designed to help students succeed in their first year of engineering. The purpose of this paper is to guide others who might be thinking about developing a first-year engineering learning center or questioning the value of creating a seemingly too-small space for their students due to limited resources. The paper will outline adjustments made and lessons learned that can be incorporated into the planning process of other educators and administrators who may be looking to provide a modest "makerspace" and hospitable centralized community area for undergraduate engineering programs and perhaps even for a high school, museum, or informal engineering education program.

Introduction

Considering the complexities of today's society, there is no doubt that colleges and universities have a critical role in preparing today's engineering students to meet the challenges of tomorrow's global problems through more interdisciplinary strategies, including problems associated with booming populations, climate change, lack of clean water, sustainability, transportation logistics, and dwindling energy resources. The current state of engineering education has been under considerable review by educators at all levels of higher education since the early 1990s with efforts dedicated to comprehensive initiatives through the National Science Foundation, National Academy of Engineering, American Society for Engineering Education, and the United States government, among others.

After a substantial review process that took several years and several committees of high ranking members from academia and industry, the National Academy of Engineering in its *Educating The Engineer of 2020* report[1] recommended in 2005 that engineering education establishments seek to achieve the following:

1. Pursue a student-centered approach to undergraduate engineering education.
2. Increase the value in engineering education research to better understand how students learn.
3. Develop new standards for faculty qualifications.
4. Help promote engineering and technological literacy among the public.
5. Introduce interdisciplinary learning at the undergraduate level.

The 5 objectives above address the perceived problem that engineering students of today may not be appropriately educated to meet the demands of being an engineer in the year 2020 and beyond. The National Academy of Engineering hoped that this call for action would initiate change in university infrastructure and engineering education policy. Unless college and university engineering programs take action now to refocus and change the undergraduate institutional system of engineering education, the number of needed, qualified, and skilled engineering graduates may decrease to a point where jobs in academia, research, business, and industry are left unfilled and global problems continue to persist.

What is known about effective engineering education stems from the fact that experiential, hands-on and interdisciplinary learning engages students and increases retention.[2,3,4,5,6] Key findings in the current literature on teaching show that real-world problems – when presented in an active and experiential learning environment – increase student interest, possess pedagogical effectiveness, and help to facilitate initial learning and transfer of that learning to other contexts.[7]

As a result of this research, engineering learning spaces, innovation zones, design studios, and student success centers are being built to support undergraduate engineering education, sometimes specifically for first-year engineering students. At the University of South Australia, for example, a large new learning space called "Experience 1 Studio" opened in 2009 to help students adapt to university life, develop peer networks, benefit from collaborative learning, and engage with their studies.[8] In fact, this learning space was shown to help students transition to college, especially women and minorities.

In 2000, the College of Engineering at the University of Notre Dame opened a 4,000 ft^2 \$1 million Engineering Learning Center to support first year courses with an enrollment of 300-400 students each semester.[9] The Center includes flexible project-team work areas with networked computer support, multiple screen audio/visual capabilities that support a variety of multi-media sources, and space for students to fabricate and store projects. Assessment data show that the Learning Center is a place for students to work on group projects and a place to study where there would be other students available for assistance or collaboration. Even upper class students comment that they wished they had access to a facility such as this in their first-year.

In 2007, Indiana University-Purdue University-Fort Wayne converted a 24 × 30 foot classroom into a new learning space.[10] The space was designed to provide for multiple modes of education in the same space with a particular emphasis on active and cooperative modes, to encourage students to develop an attachment to the engineering department space, to be a showcase for the program, and to provide a 24/7 informal learning space when not being used by classes. Assessment of the space shows that it is pleasant and well-liked by both students and faculty and is working well for teaching a range of classes.

At Michigan State University, a more comprehensive approach to first-year engineering was established in 2008 which integrated cornerstone courses, an engineering living-learning residence hall, computer labs, and a project work space.[11,12,13] Similar to Northeastern University, Michigan State's enrollment is comparable in size (about 700+ first-year engineering students each fall). Researchers discovered that engineering students living in the special residence hall attended more evening seminars and more tutoring than students who did not live there. In addition, female students were more likely to return to the engineering residence hall than males the following year. At Michigan State, cornerstone courses, living-learning communities, and engineering learning centers together have been effective in improving the quality of undergraduate engineering education especially in the first year.

At Yale University, the new Center for Engineering Innovation and Design was opened in 2009 to support the addition of 2 new engineering cornerstone courses.[14] The new center is 8,500 square feet and was designed to provide space to students and faculty for instruction, meetings, machine shop manufacturing and fabrication, plus 3D printing. After only 18 months of operation, Yale University was able to develop assessments in each engineering course to measure Student Outcomes per ABET criteria.

In 2009, Florida Gulf Coast University opened its new 70,000 ft^2 building, Holmes Hall, to students which was designed and modeled after the learning spaces at Olin College of Engineering to promote a learner-centered environment for students and faculty with a flexible and adaptable space.[15] In Holmes Hall, 30,000 ft^2 of space is dedicated to student teams to work on projects, including a variety of design studios and studio classrooms where students can access them with student ID cards any time the building is open. The spaces were planned with movable tables, white boards, and have lockable mobile carts for each design team. The development of these facilities has been shown to have clear value and support the university's vision of multidisciplinary and hands-on learning.

In 2009, the Rice University Brown School of Engineering opened the Oshman Engineering Design Kitchen.[16] This facility has a structure similar to many other university design centers and was created to provide an environment where classroom knowledge could be combined with hands-on skills to create real-world applications. The primary goals listed for the Kitchen include providing a space where undergraduate students can work on their engineering design projects, to provide enhance opportunities for students to work on real-world design challenges, and to enrich design projects with practical training in topics such as entrepreneurship. Survey results indicate that freshman students felt it helped them develop skills in engineering design and prototyping.

Finally, in its 'Living with the Lab' initiative to support over 400 first-year students, Louisiana Tech's classroom / laboratory / shop facility was designed to support 40 students at a time (working in teams of 2 to 4) and is equipped with 11 tables for project work, note taking, and group interaction.[17] The walls of the laboratory are lined with 86 linear feet of cabinets with stainless steel counter tops. The cabinets provide the work surface required for project fabrication and the storage space needed for supplies and equipment. Ten identical work stations containing a milling machine, hand drill, vise, and basic tooling are distributed around the room to allow all 40 students in the class to work simultaneously. The lab utilizes a common platform consisting of a robot kit and tool kit to facilitate project work and this has resulted in a positive boost in hands-on learning.

Background

Curriculum development and reform for the First Year Engineering Program in the College of Engineering at Northeastern University has been ongoing since it was first launched in 1999.[18-28] The first year in engineering at Northeastern is common for all majors and designed to provide experiential engineering experiences and the fundamental mathematics and science background to prepare students for subsequent courses in their chosen engineering major. Currently, students complete 3 general engineering courses (one is a 1 credit Introduction to Engineering course), 1 or 2 calculus courses depending on their Advanced Placement credit, an engineering chemistry course, and 1 physics course. The first 4-credit general engineering course GE 1110, the "design" course, is a course that focuses on learning the principles of the *engineering design process* which is the widely accepted process for engineers that is analogous to the scientific method for scientists. This is accomplished through active learning in areas such as needs assessment and problem formulation, abstraction and synthesis, analysis, and implementation, along with report writing and presentations in relation to projects that students produce in teams. In addition to several team projects, students use computer-aided-design (such as AutoCAD and SolidWorks), 3D printing, reverse engineering, and real-world interdisciplinary solutions to a variety of humanitarian problems. The second 4-credit course GE 1111, the "programming" course, focuses on *algorithmic thinking, computer programming, computations, critical problem-solving skills,* and *active learning* to solve interdisciplinary engineering problems using computer programs, programmable microcontrollers, and common electro-mechanical components that any engineer should be familiar with, regardless of major. Students in this course gain facility in the use of the C++ programming language and Mathworks' MATLAB.

Between 2011–2012 as part of a college-wide review of its engineering curriculum, the first-year engineering program was evaluated by a 14-member College of Engineering and College of Science joint committee that included faculty representation from each of the 7 engineering programs (first-year, mechanical, industrial, chemical, civil/environmental, computer, and electrical engineering) and each of the 4 science departments (physics, math, chemistry, and biology). After 12 months of work, the following First-Year Program objectives were established:

1. Provide students with the opportunity to experience engineering as an evolving, creative and interdisciplinary career that impacts global society and daily life.
2. Provide students with the opportunity to develop process-driven problem solving skills that recognize multiple alternatives and apply critical thinking to identify an effective solution.
3. Provide students with the opportunity to integrate math and science in an engineering context.
4. Create motivated and passionate engineering students by challenging them with authentic engineering problems across multiple disciplines.
5. Instill in our students the professional, personal and academic behaviors and common competencies needed to move to the next stage of their development.

The committee's final report recommended that the first-year engineering curriculum be re-designed into newly integrated and interdisciplinary cornerstone courses organized by themes such as sustainability, security, energy, and health to provide students with selection choices in their first year. Research on principles of learning has shown that students' motivation and having choices determines what they do to learn.[7] Another key directive that emerged from the committee's report was that a new interdisciplinary engineering learning space for first-year students would be needed to provide workspace, tools, and resources for the first-year engineering faculty and their students. In the past, students were asked to design and build projects but were not provided with a workspace or tools to support their efforts so the quality of their projects was sometimes disappointing to both the students and faculty, especially when the lack of tools and materials overshadowed the learning objectives and outcomes of the particular project or assignment.

In 2012, as a result of this initiative and separate curriculum reviews in the other engineering departments, Northeastern's College of Engineering decided to build a new Learning Center in the central area of the existing engineering building and to start the process of developing new pilot cornerstone courses to integrate GE 1110 and GE 1111. After determining all the needs of both the first-year engineering faculty and the first-year engineering students in terms of faculty office requirements, shared learning space, and required project workspace and resources, designs for the new Learning Center were developed by a committee. This committee included three first-year engineering faculty, a representative from the Dean's Office, an internal architect, and a hired external architect firm. After 6 months of planning and 3 months of construction, the new 1,600 ft^2 Learning Center finally opened in September 2013 in a modest renovated space as seen in Figure 1.

Figure 1. Engineering students in the new First-Year Learning Center at Northeastern University.

The Learning Center planning committee used several objectives to guide their decisions:

1. Support the 5 aforementioned goals of the First Year Engineering Program.
2. Include 4 first-year faculty offices inside the 1,600 ft^2 Learning Center and the remaining 4 first-year faculty offices nearby on the same floor of the same building, considering potential opportunities for new faculty hiring.
3. Create a flexible setting to provide students with project and collaborative workspace, including two (2) 3D printers, one (1) black/white laser printer, several network computers, and an inventory of hand tools such as cordless drills and drill bits, glue guns, pipe cutters, screwdrivers, soldering irons, multi-meters, saws, scissors, wrenches, rivet tools, and other common workshop tools.
4. Create an inviting community space for first-year engineering students to meet with faculty, TAs or classmates.
5. Provide enough storage to centralize the location of the First Year Engineering Program's curriculum and course materials, resource library, 3D printers, hand tools, student project examples, and office supplies.

Description of the Learning Center

The Learning Center includes 4 faculty offices, located in the rear of the space, a conference room, and a copy and storage room with cabinets (Figures 1 and 2). The student workspace and lounge area are located in the front of the space. Faculty mailboxes, 2 couches, and additional cabinet storage space are located to the left of the front workspace by the door. There are 12 tables in the center that can be raised and lowered, with tilt tops, enabling them to be used in multiple arrangements. The chairs can be folded up, nested, and rolled away for storage. This enables the room to be used for many purposes. The work counter in the student workspace contains cabinets above and below (lockable) for storage of all student-accessible tools such as cordless drills, drill bits, hand saws, hammers, wrenches, screwdrivers, glue guns, multimeters, soldering irons, digital calipers, clamps and vises, pipe cutters, hot glue guns, scissors, rulers, utility knives, consumables such as duct tape, masking tape, craft sticks, zip ties, string, rubber bands, and recycled cardboard plus miscellaneous hardware such as screws, nails, nuts and bolts, and eyehooks. There are 10 network computers available to the students. A water sink was installed in the corner. Two 3D printers and a black/white laser printer are located in the conference room. Four additional first-year engineering faculty offices are located in a nearby hallway, which can be seen through the glass windows of the Learning Center workspace.

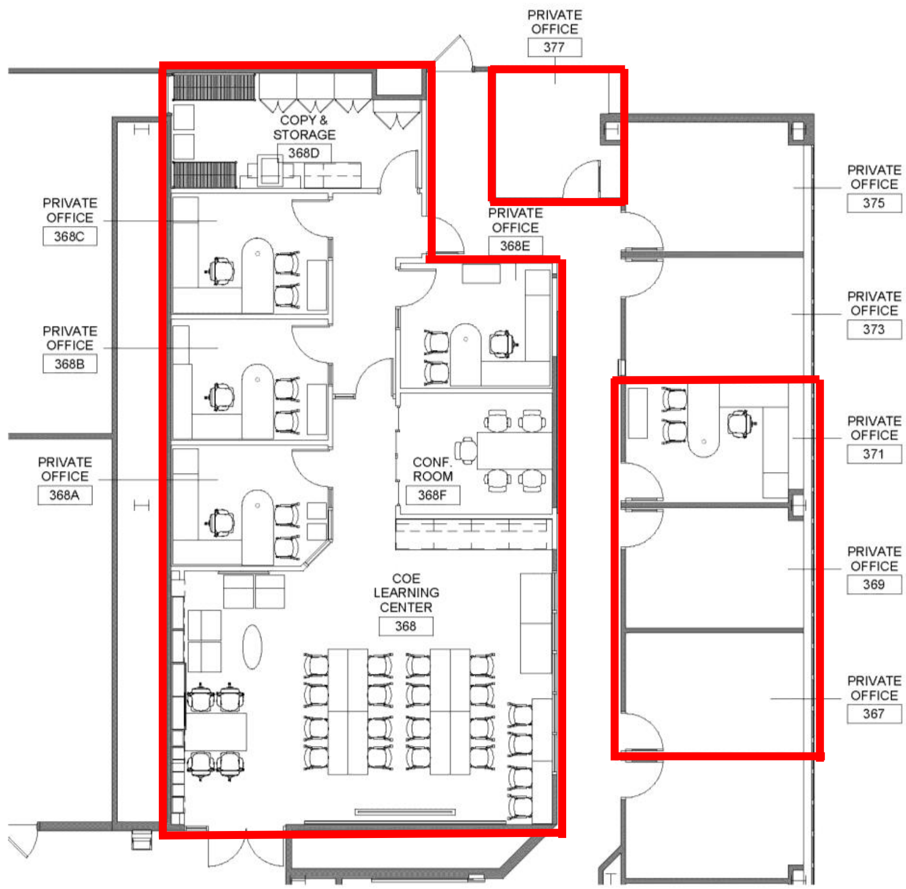


Figure 2. Floor plan of the Learning Center including 4 external faculty offices in the hallway.

Operation of the Learning Center

Open lab hours for the Learning Center during the fall and spring semesters are 12noon–9pm Mondays through Thursdays and 12noon–6pm on Fridays, for a total of 42 hours per week. These hours coincide with students' availability for working on projects. The lab is open for additional hours on select weekends prior to project due dates. Since faculty would not be able to supervise the Learning Center during all of these hours, 3 graduate students are carefully interviewed, hired, and trained to staff the Learning Center each semester. These graduate students complete the University's Lab Safety Training and are responsible for supervising undergraduate students' use of the tools in the Learning Center, in addition to providing support for students' projects and their assignments.

Research Methods to Assess the First Year Engineering Learning Center

At the end of each semester beginning in Fall 2013, over 600 students with authorized access to the Center were administered an online survey through their respective first-year classes. These were students currently enrolled in any of the General Engineering first-year engineering courses: Introduction to Engineering GE 1000, GE 1110, and GE 1111. In terms of disclosure, the primary objectives of the questionnaire were outlined at the outset. A sample survey can be found in Appendix A. This research was conducted under IRB exemption for programmatic improvement and was overseen by the First-Year Program Directors.

In an attempt to learn how the students were using the Center and how it could be improved for their purposes, the survey comprised a mixed format of questions, focusing on the following:

- Relevant demographic information: gender, relevant course in general engineering [*radio buttons*]
- Whether they had visited/used the Center [*binary yes/no*]
    - If no, whether they knew the Center existed [*binary yes/no*]
    - If they knew it existed, why they didn't visit [*checklist and open-ended response*]
- What they did when visiting the Center, what they worked on [*checklist and open-ended response*]
- Importance of the Center and its resources to their success in the semester of interest [*4-point Likert*]
- Impression of the helpfulness of the Lab Supervisors (Graduate Students) to them [*5-point Likert*]
- What they thought was missing or what they suggest to add to the Center [*open-ended response*]
- Thanking them for participating in the survey.

The results were compiled and stratified in some cases, by course of interest and in other cases by gender to ascertain patterns that may emerge along those factors. Likert-scale analyses in such cases were managed by a comparison of the central measures and data variability, accounting for the ordinal scale of the data pool.

The remainder of the data was managed by frequency analysis, characterizing the dispersion among the categories.[29] Open-ended responses were evaluated using a combination of conventional, directed, and summative multi-pass content analysis to categorize responses by patterns and categories using multiple independent coders.[30] In the full evaluation of the respondents' feedback, special attention was given to responses that would drive future planning in the following areas:

- Advertising in terms of awareness and hospitality so that students know about the Center and feel welcome there individually, in teams and as part of their classes.
- Awareness and transparency as to the facility features and available resources.
- Patterns of use for planning time, space and material.
- Requests for materials, tools and resources that would support the first-year program.

Results – Summary of Student Respondents

A summary of student survey responses by gender (Table 1) indicates that the majority of students who completed the survey and visited the Learning Center were male, although the percentages of female students in these surveys (35% Fall 2013, 38% Spring 2014 and 32% Fall 2014) were greater than the overall average of female students in the entire first-year engineering class for both Fall 2013 and Fall 2014 (28% and 26%, respectively). The fall semester survey data were dominated by students taking the design course while the spring semester survey data were dominated by students taking the programming course (Table 2), which is aligned with the course offering pattern.

Table 1. Summary of student survey responses by number and gender.

	Survey Responses	**Reponses by Gender** (*male % & female % calculated from all survey respondents*)	**Students who visited Learning Center** (*male % & female % calculated from only the students who actually visited*)	
Fall 2013	220	142 male (65%)	205	129 male (63%)
		78 female (35%)		76 female (37%)
Spring 2014	305	190 male (62%)	236	141 male (60%)
		115 female (38%)		95 female (40%)
Fall 2014	241	163 male (68%)	236	158 male (67%)
		78 female (32%)		78 female (33%)

Table 2. Summary of student survey responses by course enrollment. Highest enrollments are highlighted.

	Survey Responses	Reponses by General Engineering Course Enrollment	
Fall 2013	220	Design Course GE 1110	166
		Programming Course GE 1111	2
		GE 1110 & GE 1111 (concurrently)	52
Spring 2014	305	Design Course GE 1110	37
		Programming Course GE 1111	171
		GE 1110 & GE 1111 (concurrently)	59
		Other course	38
Fall 2014	241	Design Course GE 1110	188
		Programming Course GE 1111	1
		GE 1110 & GE 1111 (concurrently)	24
		Cornerstone (GE 1110 & GE 1111 combined)	28

Results – Student Usage of the Learning Center

The students who answered that they visited the Learning Center at least once during the semester were asked to select all applicable activities in which they participated. When the survey was originally written, various response options were chosen based on respective activities in the GE 1110 and GE 1111 courses. A summary of students' responses over the 3 semesters indicate that design-related activities such as projects, posters, tool use, and 3D printing dominated the fall semesters when the majority of the students were taking the design course (Figure 3). Programming-related activities such as computer usage, MATLAB or C++ homework, microcontroller programming assignments, and the programming final project dominated the spring semester when the majority of the students were taking the programming course. Several of the activities saw an increase in student usage from the Fall 2013 to the Fall 2014 semesters, notably the design project/poster activity, as determined from the percentages in

Figure 3. In addition, faculty also anecdotally observed an increase in student usage from Fall 2013 to Fall 2014, which was confirmed by headcount data analyzed separately.

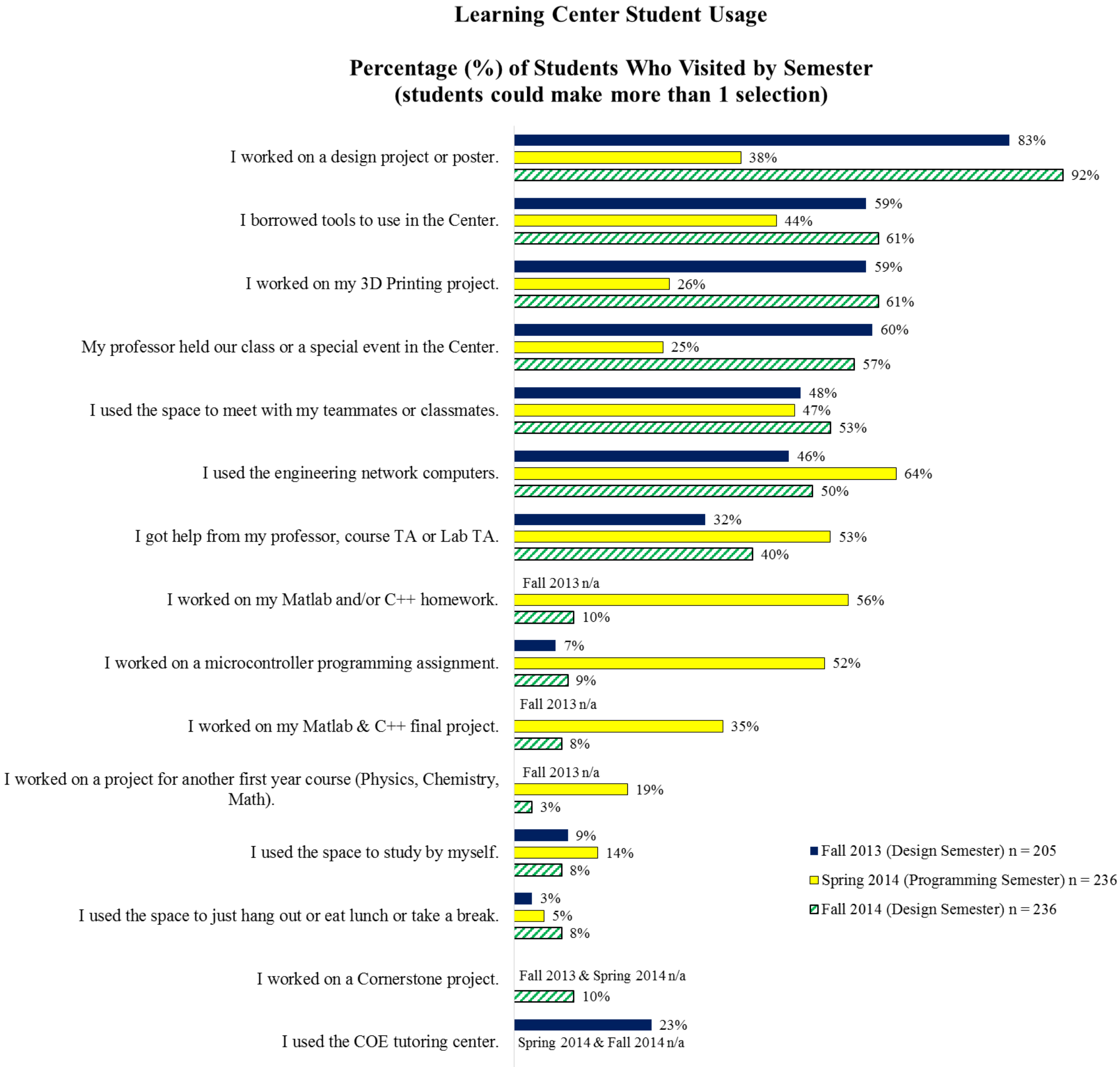


Figure 3. Percentage of student respondents who self-reported their usage of the Learning Center by activity and semester, based on students who actually visited. Students could make more than 1 selection in the survey.

Results – Importance of the Learning Center to Students' Academic Success

Of the students who visited the Learning Center, the majority of students felt that the Learning Center and its resources were "important" and "essential" to their success (Figures 4 – 6). When the number of responses was divided by the number of male or female students who actually visited the Learning Center and answered the survey question and then compared over the 3 semesters, the percentage of students who favorably rated the Learning Center increased. In Fall 2013, 81% of male students and 82% of female students rated that the Learning Center and its resources combined were "important" and "essential" to their success. In Spring 2014, 82% of male students and 85% of female students rated that the Learning Center and its resources combined were "important" and "essential". In Fall 2014, these percentages increased to 91% for males students and 96% for female students.

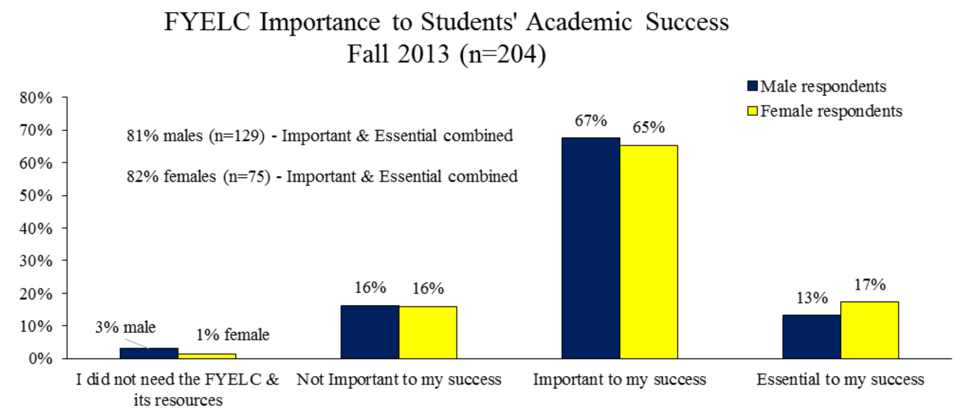


Figure 4. Engineering Learning Center importance to students' academic success, Fall 2013.

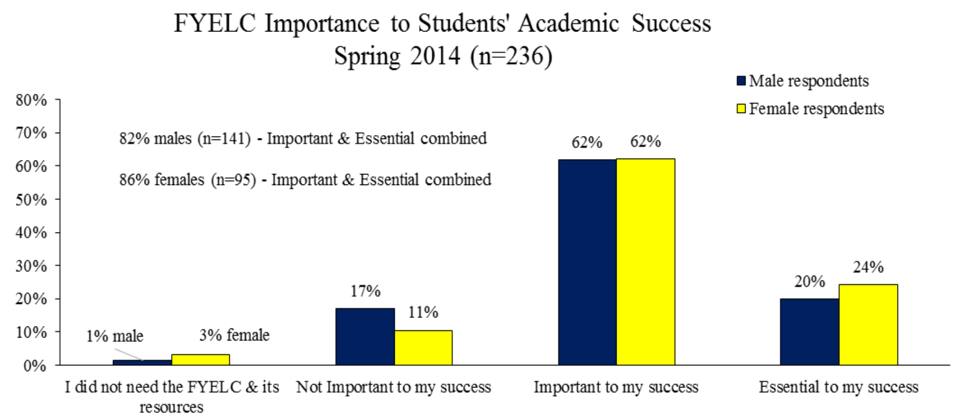


Figure 5. Engineering Learning Center importance to students' academic success, Spring 2014.

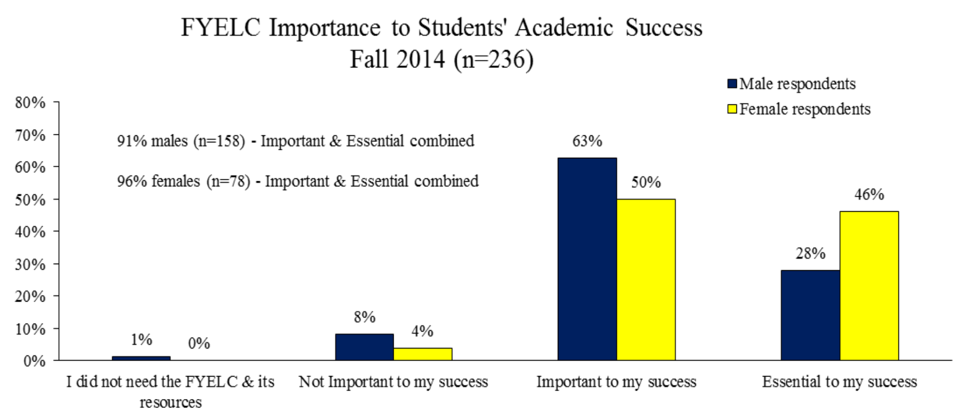


Figure 6. Engineering Learning Center importance to students' academic success, Fall 2014.

Results – Qualitative Content Analysis

The results for the open-ended question, "Are there any additional resources or improved services that you would like to see offered in the Learning Center?" from all 3 semesters of the survey are summarized in Table 3 and Figure 7.

Table 3. Qualitative content analysis of survey open-ended question. Highest percentages are highlighted.

	More Space	Materials / Tools	3D Printer	More Computers	More Help	More Hours	Workshops	Tutoring
Fall 2013 (n=39 comments)	23%	13%	13%	13%	5%	13%	3%	18%
Spring 2014 (n=48 comments)	40%	10%	2%	25%	15%	6%	0%	2%
Fall 2014 (n=78 comments)	33%	36%	14%	5%	3%	6%	1%	1%
Total % (n=165 comments)	33%	23%	10%	13%	7%	8%	1%	5%

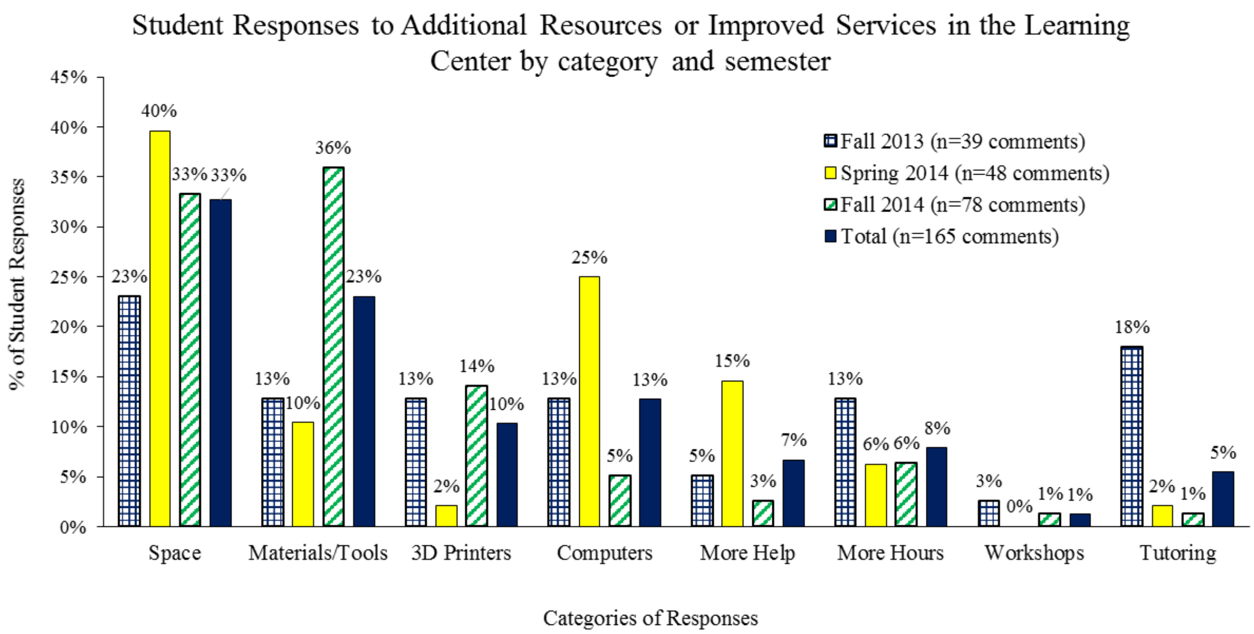


Figure 7. Student responses to the open-ended question "Are there any additional resources or improved services that you would like to see offered in the Learning Center?".

Figure 7 shows the results of multi-pass content analysis of student responses on the question of suggested improvements and additional resources. In total, the students clearly communicated that they wanted more space to meet and work. In Fall 2014, the Learning Center utilization increased, and as more students used the Center, comments increased on what the students would like to see for tooling, along with comments on the crowded space. For example, "*The space in its current form is really helpful, but it's too small to accommodate the rush of students that occurs starting a week before large projects were due. The space quickly becomes cramped if* *more than three groups are working simultaneously. A larger work space with more tables would be better I think."* In addition to comments on space, students mentioned specific tools, with comments such as, *"More power tools should be available for use here" and "A Dremel tool would be great!"* Similarly for materials, there were requests for replenishment of tape and glue, and general thoughts on more project-development materials such as cardboard, wood, and electrical wire. The peak in need for more computers occurred in the Spring 2014 semester, as expected. This is the semester when the majority of students are in the programming class.

For one semester in the Fall 2013, the tutoring center was located inside the Learning Center while the new tutoring space was being renovated. It was then moved to its current location just down the hall from our Learning Center. Comments on tutoring nearly disappeared after Fall 2013 since students did not expect the Learning Center to offer tutoring with a separate space for the Tutoring Center now open. There were many comments for the Learning Center to be open on weekends, plus longer hours. In Fall 2014, comments about more hours decreased, probably since the Learning Center had increased its weekend hours when project due dates were approaching and since the Learning Center had increased publication of those hours. In Fall 2014, increased efforts were made by faculty to stagger project due dates to reduce the load and crowding in the Learning Center.

There are a few other categories worth reviewing. The Learning Center has 2 small 3D printers. There were student comments on the need for more 3D printing machines, better machines and better access to print queue information. Historically, many of these students have had previous opportunities to explore prototyping and 3D printing in high school, so their expectations for 3D printers at a university may be quite high. Northeastern University also has a separate 3D Printing Studio in the campus library, which supports all students, so exposure to advanced technology is available. We are currently trying to determine to what extent we will provide 3D printing and prototyping services in the Learning Center without duplicating services available in the campus library. In addition, a few students suggested various kinds of workshops to learn tools and techniques for building, such as basic carpentry and fabrication skills, which we are considering offering in the Spring, Summer and Fall semesters of 2015.

Results – Helpfulness of the Graduate Student Lab Supervisors

After Fall 2013 and Spring 2014, comments on the helpfulness of the graduate student Lab Supervisors were carefully reviewed. For example, "*the TAs never identified themselves and I didn't know who to ask for help*". The use of nametags for Lab Supervisors (the TAs) is now required, and more training is done with the graduate students to encourage their "people skills" for welcoming and working with first-year engineering students. Also the graduate students' schedules were posted and became more visible over time so the first-year engineering students knew who and when to expect for available help at certain times of the day. We have also been more careful in screening graduate students when they apply for open Lab Supervisor positions at the beginning of each semester to ensure that they have all the required skill sets for the position (MATLAB, C++, AutoCAD, SolidWorks, basic electronics, 3D printing expertise and excellent communication skills). These improvements appear to have reduced the number of comments on the topic. Helpfulness ratings for the Lab Supervisors have consistently been at least 80% positive (combining ratings "they tried to help me" and "they were helpful"), as shown in Figures 8 - 10.

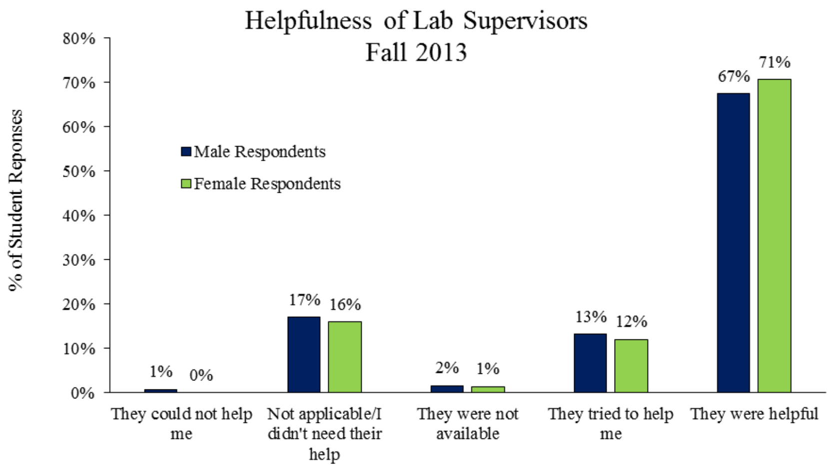


Figure 8. Helpfulness of Lab Supervisors as rated by students in Fall 2013 (n=204).

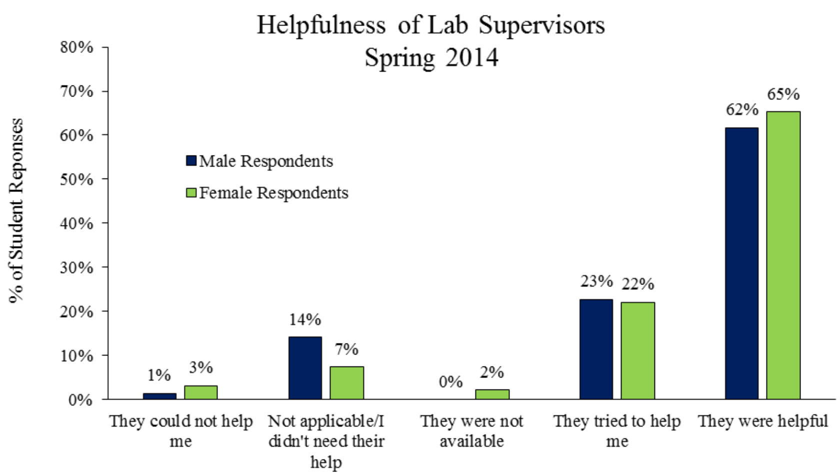


Figure 9. Helpfulness of Lab Supervisors as rated by students in Spring 2014 (n=236).

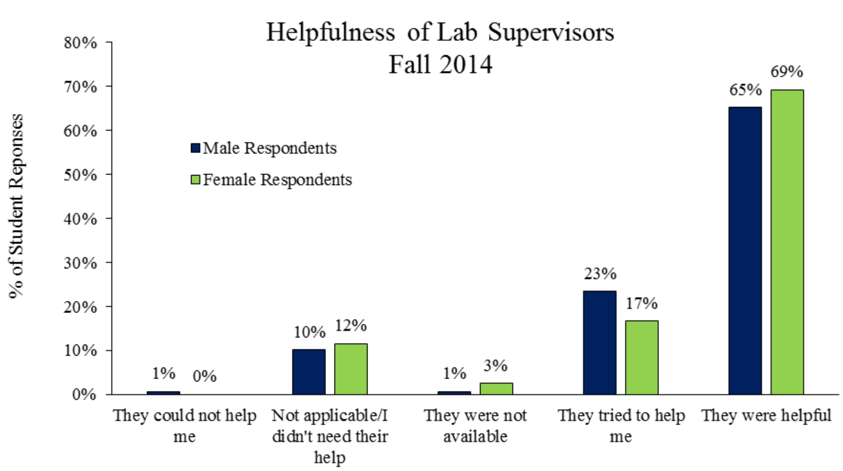


Figure 10. Helpfulness of Lab Supervisors as rated by students in Fall 2014 (n=236).

Results – Why Students Did Not Visit the Learning Center

If students did not visit the Learning Center and they knew it existed, they were asked to select all reasons for why they did not visit. In Fall 2013, 4 out of the 15 students who responded that they did not visit the Learning Center did not know it existed. Of the remaining 11 students who did not visit the Learning Center but knew it existed, they cited a total of 16 reasons including *"I didn't need or want to go there"* (n=8), *"I thought it was only for tutoring"* (n=4), *"I didn't know what resources were available there"* (n=3) and *"I didn't know if it was open"* (n=1). None of these 15 students wrote in any additional reasons for not visiting the Learning Center.

In Spring 2014, 10 out of the 69 students who responded that they did not visit the Learning Center did not know it existed. Of the remaining 59 students who did not visit the Learning Center but knew it existed, they cited a total of 85 reasons including *"I didn't need or want to go there"* (n=56), *"I didn't know what resources were available there"* (n=10), *"I didn't know if it was open"* (n=7), *"I thought it was only for tutoring"* (n=6), *"the open hours were not convenient for me"* (n=4), *"I thought it was only for faculty offices"* (n=1) and *"I thought it was only for special meetings or classes"* (n=1). One student also added that *"there are too many people there all the time. Should be bigger"* as a reason for not visiting the Center.

In Fall 2014, 4 out of the 5 students who responded that they did not visit the Learning Center did not know it existed. The remaining student who did not visit the Learning Center but knew it existed cited that *"I didn't need or want to go there"*. In summary, the small percentage of student respondents who knew the Learning Center existed but did not visit felt that they didn't need the Learning Center's resources, probably because they had their own tools or found resources elsewhere (at home, for example).

Discussion

The survey data along with our own observations and reflections enable us to summarize our thoughts on what needed to be improved, what worked, what we changed, and what could be considered accomplishments. As for what needed to be improved, we identified the number of open lab hours per week, communicating the open lab hours, our initial inventory of tools, training for the graduate student Lab Supervisors, and more computers as areas that were addressed during the first semester of operation in Fall 2013 and improved for Spring 2014. For example, in Fall 2013, there were only 5 networked computers in the Learning Center but by the beginning of Spring 2014, we had increased that number to 10. We also supplied additional cordless drills, saws, specialty screwdrivers, pipe cutters, utility knives, and electrical supplies. One improvement that we have not been able to address yet is more physical space, but we are working on a solution (as addressed in the Conclusion).

In terms of what worked well, there was a concerted effort by the first-year engineering faculty and all who planned and used the space to continually refine the operation of the Learning Center. We feel the following objectives were crucial to the Learning Center's success:

- ✓ Defining objectives and the space's intended use in advance (what the space is and is NOT intended to be).
- ✓ Concerted planning efforts by faculty and the graduate student Lab Supervisors.

- ✓ Polling and involving multiple faculty in the planning and decision-making process.
- ✓ Creating a hospitable community setting for first-year engineering students (you can come in by yourself for help, meet with your teammates or get to know your faculty).
- ✓ Being agile and evolving (the multi-use space can easily reconfigure with movable chairs and tables, can be converted into a classroom, workshop, meeting or open space).

Challenges and adjustments are ongoing as with any new program. Although we have made some changes and improved some deficiencies, we continue to work on the areas identified through these surveys. We are working to make sure we maintain quality help, safe and productive facilities and an inviting community atmosphere. Areas that were critical challenges and informed adjustments were:

- Scheduling of course design projects, which are now purposely staggered to alleviate overcrowding of students and project materials in the space.
- Creating a mobile toolbox to bring the Learning Center to the student dorms during high usage periods to alleviate overcrowding of the space.
- Temporarily expanding into a vacant classroom next door to provide additional work space during extremely high usage days and weekends.
- Defining the Learning Center to all relevant faculty, students, and administrators as a combination of "workshop", "lab", "meeting place" and "community center" without misrepresenting the Center as only one of these types of spaces.
- Improving the Lab Supervisors' low profile by adopting the use of name tags, posted schedules, and improved "customer service" training.

Adjustments made after the survey in Fall 2013 appear to have reduced some of the issues that students have identified. In addition, we made more effort to get the word out to the first-year students about the existence of the Learning Center and what resources were available, which resulted in the need for even more space and tools. As we have often found, the more we do and provide, the more the students seem to request, and the more ideas we have to improve upon.

Conclusions & Recommendations for Future Work

Even with only 700 ft^2 of student workspace within the Learning Center's total of 1,600 ft^2, we have been able to accomplish several objectives for our first-year engineering program, its curriculum and for our students:

- ✓ A collaborative workspace with access to hand tools, computer lab, and community center for first-year engineering students where none existed before.
- ✓ The infrastructure for more advanced design projects and more advanced outcomes due to improved resources for the students.
- ✓ A place for students and faculty to meet, connect, innovate, tinker, plan, create, develop, build, and accomplish.
- ✓ A high profile hub of activity and creativity (for college, visitor/parents, and upper level faculty) to see what is being offered in the first-year engineering curriculum.

- ✓ An environment where failures, challenges, and successes are shared between faculty and students.
- ✓ An opportunity for first-year engineering students to connect with graduate students and for graduate students to serve as role models.
- ✓ A safe and supportive setting where students can be inspired and motivated to press on, be persistent, and have grit.[24]

After this year, we can now pursue more, provided we are supported by an adequate budget. We are looking for ways to expand our space, and add more tools, more computers, more materials, and more 3D printers. These messages have been clear, both from our data and from the time we spend with our students. They tell us in many ways, many times, what they would like to see added. We have numerous upper-class students come in, using the space and resources when they can, and remarking that they wish the space had been there when they were first-year students. We also are looking closely at what we did not use. Our conference room turned out to be our 3D printer room, and was not laid out correctly for actual meetings of our growing department. We have plans to improve this configuration by moving the 3D printers into the workspace, assuming we are able to expand into another space next door. We organized our materials and tools, but realize that the work flow could be improved to facilitate easier access by students. For example, we have added color pictures on the tool cabinets and drawers to more easily identify what is located in each. We now have an industrial engineering student helping us use Lean Tools[31] such as 5S which improve processes, including sorting and straightening. In addition, the student is creating a database system to improve the inventory of materials, their access, and subsequent replenishment of consumables such as tape, glue, fasteners, and miscellaneous hardware.

We have also hired a student to improve publicity and branding. This includes adding a social media presence and high quality graphics to showcase the Center so that it is more visible to the rest of the College, to prospective students, and visitors. The goal is to better manage all of our assets and facilities efficiently and effectively for our growing first-year engineering enrollment, current students, and for the first-year faculty. The development of the center has clearly met the original goals of the team of planners and with clever adjustment to its implementation has now become a principal facility for our first-year students, inspiring us to now expand and improve. The Learning Center, though limited in size and facilities, has become a center for community, for problem-solving, for teamwork, for hands-on projects, prototyping, and learning. It is a new physical space and resource for first-year students and faculty where none existed before.

References

1. National Academy of Engineering. (2005). *Educating the engineer of 2020: Adapting engineering education to the new century*. Washington, D.C.: National Academies Press.

2. Ambrose, S. A., & Amon, C. H. (1997). Systematic design of a first-year mechanical engineering course at Carnegie Mellon University. *Journal of Engineering Education, 86*(2), 173-181. doi:10.1002/j.2168-9830.1997.tb00281.x

3. Dym, C. L., Sheppard, S. D., & Wesner, J. W. (2001). A report on Mudd Design Workshop II: "Designing design education for the 21st century". *Journal of Engineering Education, 90*(3), 291.

4. Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education, 94*(1), 103-120.

5. Dym, C. L., Gilkeson, M. M., & Phillips, J. (2012). Engineering design at Harvey Mudd College: Innovation institutionalized, lessons learned. *Journal of Mechanical Design, 134*(8) doi:10.1115/1.4006890

6. Gasiewski, J. A., Eagan, M. K., Garcia, G. A., Hurtado, S., & Chang, M. J. (2012). From gatekeeping to engagement: A multicontextual, mixed method study of student academic engagement in introductory STEM courses. *Research in Higher Education, 53*(2), 229-261.

7. Ambrose, S. A. (2010). *How learning works: Seven research-based principles for smart teaching* (1st ed.). San Francisco, CA: Jossey-Bass.

8. Quinn, D., Smith, E. J., & Mahfuzul Aziz, S. (2011). First year engineering learning space enhancing the student experience. *American Society for Engineering Education National Conference,* Vancouver, British Columbia, Canada, *Paper ID #1311.*

9. Batill, Stephen M. and Gedde, N. (2001). Development of a multidisciplinary Engineering Learning Center. *American Society for Engineering Education Annual Conference,* Albuquerque, New Mexico, Paper ID #251.

10. Moor, S. (2008). Case study: A space designed for cooperative learning with multiple processes. *American Society for Engineering Education Annual Conference,* Pittsburgh, PA, Paper ID #1440.

11. Hinds, T., Wolff, T., Buch, N., Idema, A., & Helman, C. (2009). Integrating a first-year engineering program with a living-learning community. *American Society for Engineering Education Annual Conference,* Austin, TX, *Paper ID #1922*

12. Hinds, T., Wolff, T., Buch, N., Idema, A., & Davis-King, C. (2010). First-year engineering: A comprehensive approach. *American Society for Engineering Education Annual Conference,* Louisville, KY, *Paper ID #1502.*

13. Walton, S. P., Briedis, D., Urban-Lurain, M., Hinds, T., & Davis-King, C. (2013). Building the whole engineer: An integrated academic and co-curricular first-year experience. *American Society for Engineering Education Annual Conference,* Atlanta, GA, *Paper ID #7410.*

14. Wilczynski, V., O'Hern, C. S., & Dufresne, E. R. (2014). Using an engineering design center to infuse design experience into a mechanical engineering program. *American Society for Engineering Education*, Indianapolis, IN, *Paper ID #9822.*

15. Blanchard, S., O'Neill, R., Sweeney, J., Zidek, L., Komisar, S., and Stoppiello, D. (2010). Re-inventing engineering education one new school at a time. *American Society for Engineering Education Annual Conference,* Louisville, KY, Paper ID #922.

16. Saterbak, A., Embree, M. and Oden, M. (2012). Client-based projects in freshman design. *American Society for Engineering Education Annual Conference,* San Antonio, TX, Paper ID #4037.

17. Hall, D., Barker, M., & Nelson, J. (2009). Living with the lab: Update on the second year of full implementation for over 400 first-year engineering students. *American Society for Engineering Education Annual Conference*, Austin, Texas, Paper ID #1280.

18. Freeman, S. F., Jaeger, B. K., & Brougham, J. C. (2003). Pair programming: More learning and less anxiety in a first programming course. *American Society for Engineering Education Annual Conference,* Nashville, TN., *Paper ID #359.*

19. Whalen, R., Freeman, S. F., Jaeger, B. K., & Maheswaran, B. (2005). Teamwork is academic: The gateway approach to teaching engineering freshmen. *American Society for Engineering Education Annual Conference,* Portland, OR, *Paper ID #103.*

20. Freeman, S., Jaeger, B. K., & Whalen, R. (2006). Active teaching, active learning: Infusing the design process into a first-year course. *American Society for Engineering Education Annual Conference,* Chicago, IL, *Paper ID #1001*.

21. Jaeger, B. K., & Bilen, S. (2006). The one-minute engineer: Getting design class out of the starting blocks. *American Society for Engineering Education Annual Conference,* Chicago, IL, *Paper ID #911.*

22. Jaeger, B. K., Bates, M., Damon, B., & Reppy, A. (2008). Tipping the scales: Finding the most effective balance between lecture versus active learning across academic levels in engineering. *American Society for Engineering Education Annual Conference,* Pittsburgh, PA, *Paper ID #2574.*

23. Whalen, R., Freeman, S. F., & Jaeger, B. K. (2008). Agile education: What we thought we knew about our classes, what we learned, and what we did about it. *American Society for Engineering Education Annual Conference,* Pittsburgh, PA, *Paper ID #1647.*

24. Jaeger, B. K., Freeman, S. F., Whalen, R., & Payne, R. (2010). Successful students: Smart or tough? *American Society for Engineering Education Annual Conference,* Louisville, KY, *Paper ID #1033.*

25. Whalen, R., Jaeger, B. K., & Freeman, S. F. (2011). R U all there? texting, surfing, and e-tasking in the classroom and its effects on learning. *American Society for Engineering Education Annual Conference,* Vancouver, British Columbia, Canada, *Paper ID #537.*

26. Jaeger, B. K., Freeman, S. F., & Whalen, R. (2012). Programming is invisible or is it - how to bring a first-year programming course to life. *American Society for Engineering Education,* San Antonio, TX, *Paper ID #4011.*

27. Freeman, S. F., Jaeger, B. K., & Whalen, R. (2014). Making a first-year impression: Engineering projects that affect and connect. *American Society for Engineering Education Annual Conference*, Indianapolis, IN, *Paper ID #9599*.

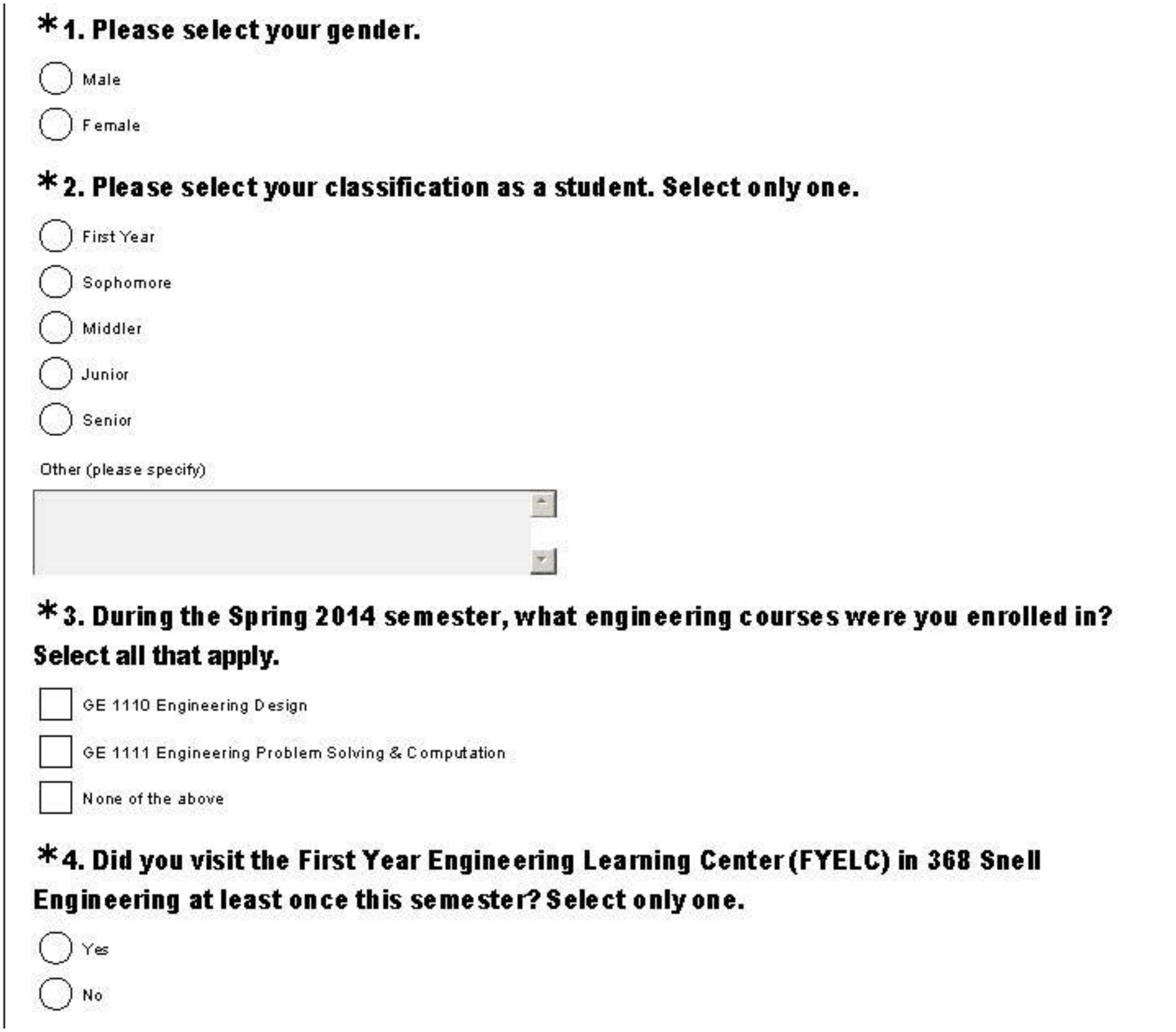
28. Love, J., Freeman, S. F., & Sullivan, D. (2014). What sticks with first year engineering students and engineering faculty in STEM education service-learning projects? *American Society for Engineering Education Annual Conference*, Indianapolis, IN, *Paper ID #10112.*

29. Jackson, K.M. & Trochim, W.M.K. (2002). Concept mapping as an alternative approach for the analysis of open-ended survey responses. *Organizational Research Methods*, 5:4, October, 307-336.

30. Hseih, H-F. & Shannon, S.E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, November 2005 15:9, 1277-1288.

31. http://www.leanproduction.com/top-25-lean-tools.html. Website accessed February 1, 2015.

Appendix A – Survey (Spring 2014 example)



***1. Please select your gender.**

- ○ Male
- ○ Female

***2. Please select your classification as a student. Select only one.**

- ○ First Year
- ○ Sophomore
- ○ Middler
- ○ Junior
- ○ Senior

Other (please specify)

***3. During the Spring 2014 semester, what engineering courses were you enrolled in? Select all that apply.**

- ☐ GE 1110 Engineering Design
- ☐ GE 1111 Engineering Problem Solving & Computation
- ☐ None of the above

***4. Did you visit the First Year Engineering Learning Center (FYELC) in 368 Snell Engineering at least once this semester? Select only one.**

- ○ Yes
- ○ No

***5. What did you do in the First Year Engineering Learning Center (368SN) during any of your visits? Select all that apply.**

- [ ] I worked on my GE1110 Minor Design Project (at the beginning of the semester).
- [ ] I used the College of Engineering (COE) computers.
- [ ] I got help from my professor, course Teaching Assistant (TA) or a FYELC Lab Supervisor.
- [ ] My professor held our class or a special event in 368SN.
- [ ] I worked on a GE1110 construction project and/or poster.
- [ ] I used a Cube 3D Printer for a course project and/or assignment.
- [ ] I worked on my GE1111 Matlab or C++ assignment(s).
- [ ] I worked on my GE1111 Machine Science assignment(s).
- [ ] I worked on my GE1111 Final Integrated Project.
- [ ] I worked on a project for another first year course such as Physics, Chemistry or Calculus.
- [ ] I used the space to study by myself.
- [ ] I used the space to just hang out or eat lunch or take a break.
- [ ] I used the space to meet with my team or classmates.
- [ ] I borrowed tools to use in 368 SN.

Other (please specify)

***6. How would you describe the IMPORTANCE of the FYELC SPACE and its RESOURCES (tools, free materials, 3D printer, computers, workbench, large tables, etc) to your academic success this semester?**

- ○ Essential to my success
- ○ Important to my success
- ○ Not Important to my success
- ○ I did not need the FYELC and its resources

Comments

Appendix A – Survey (Spring 2014 example)

***7. How would you describe the HELPFULNESS of the LAB SUPERVISORS who were working in the FYELC? Check one that best represents your overall experience with the Lab Supervisors.**

- ◯ They were helpful.
- ◯ They tried to help me.
- ◯ They could not help me.
- ◯ They were not available.
- ◯ Not applicable / I didn't need their help.

Comments

***8. Did you know that the First Year Engineering Learning Center in 368SN existed?**

- ◯ Yes
- ◯ No

*** 9. If you did not visit the FYELC but knew it existed, why did you not go there? Check all that apply. Please write in any comments or additional selections, if applicable.**

☐ I thought it was only for tutoring.

☐ I thought it was only for faculty offices.

☐ I thought it was only for special meetings or classes.

☐ I didn't know what resources were available there.

☐ I didn't know if it was open.

☐ The open hours were not convenient for me.

☐ I didn't need or want to go there.

Other (please specify)

10. Are there any additional resources or improved services that you would like to see offered in the First Year Engineering Learning Center? If yes, please explain.