AC 2012-4743: BECOMING AN ENGINEER: ASSESSING THE IMPACT OF A SHORT WORKSHOP ON INCOMING ENGINEERING STUDENTS' UNDERSTANDING OF ENGINEERING DESIGN

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Becoming an Engineer*: Assessing the impact of a short program on incoming engineering students' understanding of engineering* design

abstract

Engineering students begin their education with varying understanding of the engineering design process. Effective engineering education will require us to understand how students develop both skills and a concept of engineering design. At a large Midwestern public university we compare 100 students' initial conceptions in design and response to design tasks both before and after a 2-day, peer mentor led, design activity program which preceded the beginning of the first year in engineering. During the program, students were led through two design activities: one focusing on idea generation and customer requirements; the second focusing on a design, build and test activity. In addition, there were faculty presentations and discussions led by peer mentors. We also compare 35 incoming students who did not participate in the program. This program is the initial activity in an undergraduate multidisciplinary design program which includes many co-curricular enrichment activities as well as an academic minor. We intend to study this group of students through their engineering education and evaluate them periodically. We use both the self-efficacy survey from Carberry, Lee and Ohland (*Measuring Engineering Design Self-Efficacy*) as well as the concepts in design survey from Oehlberg and Agogino (*Undergraduate Conceptions of the Engineering Design Process: assessing the Impact of a Human-Centered Desgin Course* – which is an extension of Mosborg S., et.al., *Conceptions of the Engineering Design Process: An Expert Study of Advanced Practicing Professionals*) extending them to the incoming university student population.

We consider how students' concept of design changes pre and post program and compare them with the results of upperclassmen from Oehlberg and Agogino and with practicing engineers in Mosborg. Generally students undervalued concepts related to generating alternative ideas as well as identifying hard constraints of the system compared with practicing engineers. The post program responses showed limited change from pre-program responses. Program students most closely resemble the Intermediate group (engineering students) of Carberry, Lee and Ohland in terms of self-efficacy and the High group (engineering professors and professionals) for motivation, expectancy and anxiety.

We plan to follow this group of students through their first year of engineering and re-evaluate near the end of the academic year.

educational outcomes

At Michigan Engineering, students are encouraged to work across engineering disciplines and build competencies beyond engineering. In addition to providing students with a superior technical education, Michigan Engineering is committed to teaching students the value of creativity, teamwork, and engineering design. The design immersion program is intended to introduce incoming students to these key aspects of the Michigan Engineering curriculum and culture, and to offer them direct experience with the creative process of engineering. An innovative experience , the program provides insight into the collaborative problem-solving practice that anchors Michigan Engineering. It is also a unique opportunity for participants to work closely with faculty advisors and upper-class student mentors, as well as to meet other first-year students prior to the start of classes.

class demographics

100 incoming first year students participated in the Design Immersion program. Although the University of Michigan has a significant international undergraduate population all participants in the 2011 Design Immersion program were U.S. residents because the dates conflicted with international student orientation. The participants were chosen from 375 applicants to mirror the incoming first year class to represent all majors within the college (as well as those who were still undecided) and included a diverse representation of ethnicity, gender, as well as in-state/out of state and urban/rural home locations. Students entered with a range of previous design experience from none to significant. .

Table 1: Design Immersion Participant Demographics

Demographic Group	Percentage Representation in Design Immersion Program	Percentage Representation in Incoming Freshman Class
Male	70	77
Female	30	23
Ethnicity		
Multiracial	2	3
Asian	16	14
Black	4	3
Hispanic	7	4
Not Indicated	10	2
White	60	59
Intended Major		
Aerospace Engineering	8	9
Atmospheric, Oceanic and Space Sciences	2	0
Biomedical Engineering	7	17

Chemical Engineering	7	10
Civil Engineering	8	5
Computer Science	5	11
Electrical Engineering	7	6
Industrial Operations Engineering	8	3
Materials Science Engineering	6	2
Mechanical Engineering	5	15
Naval Architecture & Marine Engineering	12	1
Nuclear Engineering & Radiological Sciences	4	2
Undecided	4	16
Home Location		
In State	58	61
Out of State	42	39

peer mentors

An important component of the program was the use of upper-class undergraduate and graduate students to serve as peer mentors assigned to a small participant group. The peer mentors serve as guides for the first-year students throughout the program, foster a collaborative learning environment and provide technical support when necessary. Twenty-five current students were recruited by reaching out through the Multidisciplinary Design Program, Center for Entrepreneurship and Engineering student organizations and encouraging them to apply. Peer mentor qualifications included good academic standing, strong experience with collaborative teams, knowledge of the engineering design process, excellent communication and small group facilitation skills. Compensation for peer mentors was a $540 stipend (approximately $10/hour) and meals throughout training and program duration.

Peer mentor training lasted approximately eight hours and was held directly before the start of the Design Immersion program.

Training components included:

- Overview of the Design Immersion Program
- Mentor Expectations
- Schedule and Logistics Review
- Presentations on Center for Entrepreneurship and Multidisciplinary Design Program
- Group Facilitation Skill Building
- Bus Stop Design Challenge Review
- Design Challenge Review
- Marshmallow Challenge

While interacting with Design Immersion participants Peer Mentors were specifically asked to emphasize the following points using illustrations from the design immersion activities as well as their own experiences.

- the creative and iterative nature of engineering design,
- the importance of understanding customer requirements (voice of the customer) and its similarities in entrepreneurship and engineering design, and
- the importance of teamwork.

Once Design Immersion began, peer mentors assisted with registration, material distribution, session preparation and clean-up, transporting students throughout campus, small group facilitation and overall energy and enthusiasm among the first year participants.

the design immersion program activities

The design immersion program included a number of activities, each meant to illustrate important aspects of the design process.

1. Marshmallow Challenge -- the value of testing prototypes
2. Design Primer Presentation – general knowledge of a process that can be learned, practiced and perfected
3. Bus Stop Challenge – understanding the determining the voice of the customer, teamwork
4. Rube Goldberg – creativity, fabrication, reliability, quality, teamwork
5. Faculty Lecture – real world illustration of design process

Marshmallow Challenge

Immediately after the program welcome by the Associate Dean for Undergraduate Education, the first experiential activity, the Marshmallow Challenge (created by Tom Wujec), was held. Upon registration, participants were placed into a small group of five and sat together as a group. Each group was given 20 sticks of spaghetti, one yard of tape, one yard of strong and one marshmallow. In eighteen minutes, groups were instructed to build the tallest free-standing structure out of their materials with the marshmallow on top. At the end of the time period, each structure was measured to determine the height. A large group debrief followed the activity led by a peer mentor and discussed different group approaches, use of materials, and problems encountered during the build. The critical learning moment happened when the peer mentor shared that the most successful completion of this project has been kindergarten students, who jump into the task and allow ample time for iteration. The activity served as the introduction to creativity, innovation, and the importance of testing/prototyping – key concepts for the Design Immersion program.

design primer presentation

While the primary aspect of Design Immersion was experiential learning, it was important to include a brief presentation outlining the principles of successful engineering design. Led by Dr. Shanna Daly, assistant research scientist and adjunct lecturer, participants considered several components such as design-build-test models, decision-making, iteration, recognition of the problem, and end user identification. Using the Marshmallow Challenge activity as reference, this session provided participants and peer mentors common language and understanding as the program began.

bus stop challenge

The Bus Stop Challenge was created to give students a hands-on experience focusing on the first part of the design process (customer discovery, requirements, idea generation) over a five and a half hour timeframe. The Bus Stop Challenge emphasized the concepts of customer discovery and needs assessment, as well as to give students the opportunity to practice interviewing and observing potential stakeholders. It also instructed students on how to pitch an idea. The students were placed into teams of five with a peer advisor to assist.

For the bus stop challenge, students considered the following question: "How might we increase face-to-face socializing and relationship building at University of Michigan bus stops?" The students were given the following design brief to provide context to the question:

Thousands of University of Michigan students take the bus to travel between North Campus and Central Campus (~2 miles). And most of these students never connect because they are too busy listening to their iPods, playing with their smart phones, or reading a book. Part of the college experience is meeting and connecting with others. Both the bus stops and the actual buses are perfect physical locations that can be redesigned to better facilitate socializing and relationship building.

Your challenge is to observe and interview actual bus users to better understand what students currently do at bus stops and/or on buses, and to innovate new designs that will incentivize relationships and interactions.

All students were provided with a pamphlet detailing step-by-step instructions for the challenge. (See Table 2 in appendix);

After students created a pitch video, they uploaded the video to Facebook and were encouraged to tell friends, family, and other program participants to "like" their video. The top three teams with the most "likes" by noon the next day were chosen as finalists in the challenge. The winner was decided by a panel of faculty and staff and announced at the closing dinner.

design fabrication challenge: rube goldberg ping pong ball launch

This design challenge activity provided the students with a rigidly assigned customer requirement to design Rube Goldberg machine with a minimum of three steps capable of delivering a ping pong ball consistently into a garbage can located 10 ft. from the Rube Goldberg machine. (This activity used as its starting point a similar activity run at Louisiana State University). The students' time focused on the later part of the design process: prototyping, building, testing, and refinement.

Students were placed in teams of five (different groups than used for the Bus Stop Challenge) with a peer mentor to coach and illustrate the ideas of the design process as the team encountered them. Each team was provided with an identical cardboard box of common office materials (see Table 3 in appendix for detailed contents).

The challenge culminated in a competition where each team had three trials to land their ping pong ball in the garbage can located 10 ft. away. Points were awarded for accuracy (100 for 3 successes, 50 for 2, 25 for 1 and disqualification from further competition if 0). Further points were then awarded by judges for extra steps in the Rube Goldberg mechanisms and general quality of construction.

faculty lecture

As part of the program, students were required to attend an inspirational and informative lecture by a guest speaker. The purpose of this talk was to demonstrate the function of engineering design methodologies in the real world, thereby validating the relevancy, value, and potential of the principles introduced during the program. The lecture was given by Anthony England, Professor of Electrical Engineering and Computer Science & Professor of Atmospheric, Oceanic and Space Sciences, University of Michigan College of Engineering.

Prior to joining the University of Michigan, Professor England was an astronaut and scientist for NASA. While at NASA, he was a support crewman for the Apollo 13 & 16 flights. In preparation for his lecture, students were invited to a special screening of the movie *Apollo 13*. During his lecture, Prof. England spoke to students about the problems that arose during that particular space mission and the way he and his teammates employed engineering design principles to innovate solutions in a high-pressure situation. He also spoke of his research as a NASA scientist and his space flight experience as a crew member of STS-51F Spacelab-2. From this lecture, students gained insight into engineering career opportunities and the practical application of research, design, innovation, and critical thinking.

additional activities

Beyond the introduction and application of critical engineering concepts mentioned earlier in this paper, larger goals around college student development were also achieved. . The program intended to build energy and excitement about the College of Engineering, the University of Michigan and about the field of engineering in general among the participants. Peer mentors used transition times to talk about a myriad of subjects – from the first football game of the season to the introductory programming course required for all engineers – or to play energizer games outside. The use of peer mentors created opportunities to make connections with students, understand campus culture, and see models of student success all of which served as valuable experiences for first year students to feel confident about being a Michigan Engineer.

Student Understanding of Design

Students were asked to complete both the self-efficacy survey from Carberry, Lee and Ohland as well as the design survey from Oehlberg and Agogino (based on Mosborg S., et. all) in the week before the program and between ten and fourteen days afterwards. 66 students fully completed both pre and post surveys. A second group of incoming first-year students who did not attend the program were asked to complete the pre- and post- surveys with only thirteen students fully completed both pre and post surveys. This low value casts doubt on the robustness of the control group results. These students will be followed through first year of engineering and surveyed near the end of the academic year.

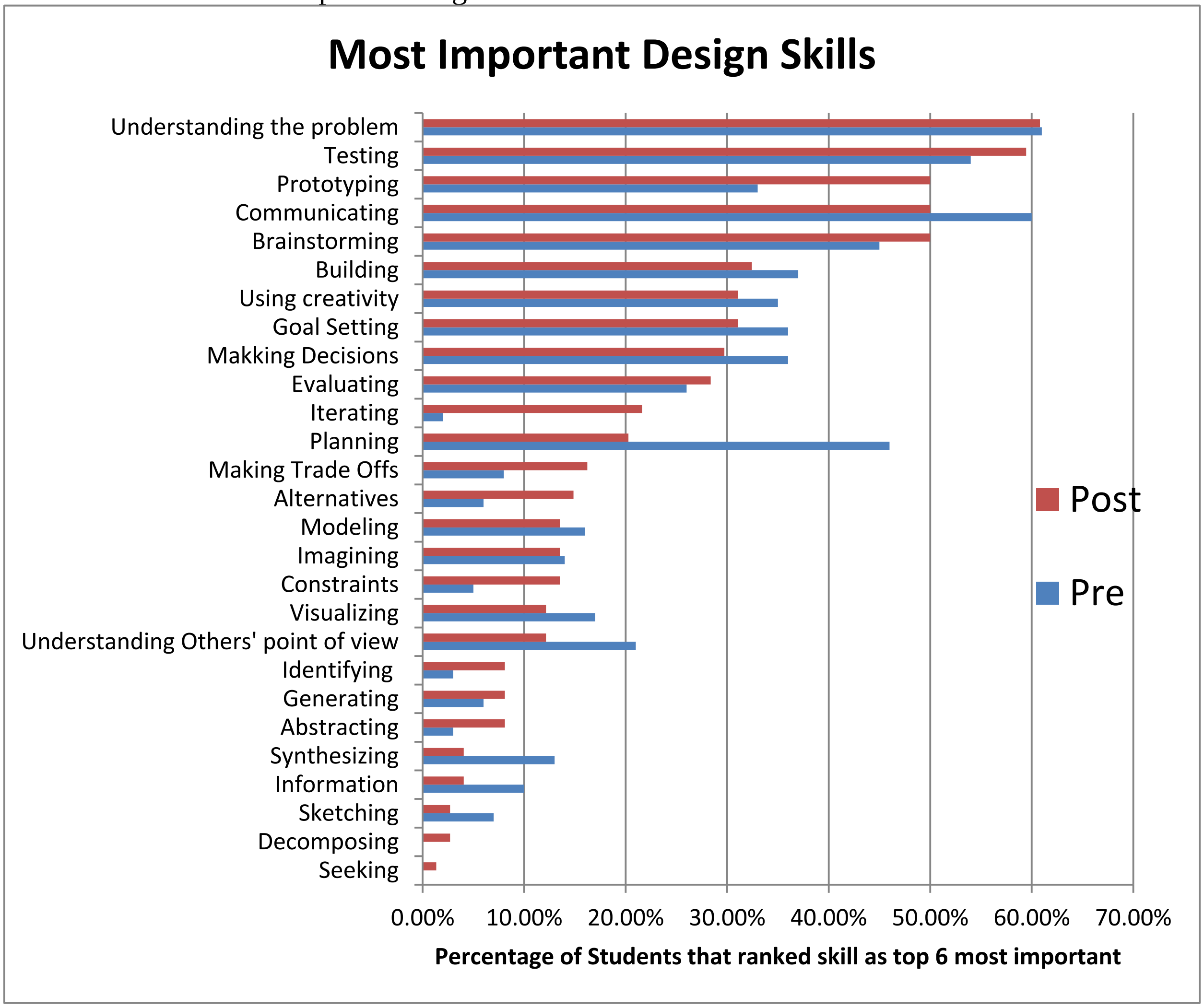
Table 2: Self Efficacy Results

	PRE DI		POST DI		PRE Control		POST Control	
	Mean	**St. Dev**	**Mean**	**St.D**	**Mean**	**St.D**	**Mean**	**St.D**
Self Efficacy	**6.68**	**2.11**	**8.08**	**1.31**	**5.84**	**2.86**	**7.31**	**1.59**
Motivation	7.93	1.80	8.00	1.81	**8.41**	**1.90**	**7.58**	**1.73**
Outcome Expectancy	**7.21**	**1.69**	**7.79**	**1.68**	6.74	2.62	7.11	1.74
Anxiety	3.54	2.73	3.46	2.80	4.55	3.32	4.33	2.48

Of these measurements changes shown in bold are significant (p=0.01 2 tailed, test). The Self Efficacy value increases were significant. The main difference between the groups is those that attended Design Immersion had a stronger belief in their ability to be successful in the design process.

Program students most closely resemble the Intermediate group (engineering students) of Carberry, Lee and Ohland in terms of self-efficacy and the High group (engineering professors and professionals) for motivation, expectancy and anxiety.

Table 3: Students' Concepts of Design Activities



Of the most important design skills, students changed their thoughts by significantly increasing the importance of iterating while decreasing importance of planning. Otherwise, increases in importance of testing, prototyping, brainstorming were consistent with the messages of peer mentors, staff and faculty as well as the educational outcomes of the program.

Table 4 Statements on Design (significant change is noted by **)

	Pre DI Data		Post DI Data	
	Mean	St. Dev	Mean	St. Dev

A. Good designers get it right the first time	1.75	0.80	1.65	0.72
B. Good designers have intrinsic design ability	3.40	0.79	3.06**	1.00
C. In design, a primary consideration throughout the process is addressing the question "Who will be using this product?"	4.25	0.67	4.21	0.70
D. Visual representations are primarily used to communicate the final design to a teammate or the client.	3.60	0.89	3.70	0.84
E. Engineering design is the process of devising a system, component or process to meet a desired need.	4.16	0.57	4.22	0.63
F. Design in a major sense is the essence of engineering: Design, above all else, distinguishes engineering from science.	3.63	0.89	3.92**	0.96
G. Design begins with the identification of a need and ends with a product or system in the hands of a user.	4.02	0.79	4.06	0.74
H. Design is primarily concerned with synthesis rather than analysis, which is central to engineering science.	2.78	0.91	3.02	0.92
I. ...design is a communicative act directed towards the planning and shaping of human experience. The task of the designer is to conceive, plan and construct artifacts that are appropriate to human situations, drawing knowledge and ideas from all the arts and sciences.	4.08	0.66	3.95	0.73
J. Design is as much a matter of finding problems as it is of solving them.	4.10	0.96	4.05	0.96
K. In design it is often not possible to say which bit of the problem is solved by which bit of the solution, One element of a design is likely to solve simultaneously more than one part of the problem.	3.65	0.77	3.63	0.77

L. Design is a highly complex and sophisticated skill. IT is not a mystical ability given only to those with deep, profound powers.	3.97	0.88	3.75	1.14
M. Designing is a conversation with the materials of a situation.	3.52	0.67	3.63	0.87
N. Design defines engineering. It's an engineer's job to create new things to improve society.	3.92	0.94	3.89	0.79
O. Design is not description of what is, it is the exploration of what might be.	4.02	0.75	4.02	0.81
P. Design is often solution-led, in that early on the designer proposes solutions in order to better understand the problem.	3.57	0.73	3.56	0.93
Q. In design, the problem and the solution co-evolve, where an advance in the solution leads to a new understanding of the problem, and a new understanding of the problem leads to a "surprise" that drives the originality streak in a design project.	3.97	0.80	4.02	0.63
R. Design is a goal-oriented, constrained, decision-making activity.	3.37	1.04	3.51	0.97
S. Designers operate within a context which depends on the designer's perceptions of the context.	3.52	0.80	3.78**	0.83
T. Creativity is integral to design, and in every design project creativity can be found.	4.32	0.67	4.24	0.67
U. Engineering design impacts every aspect of society.	4.27	0.92	4.32	0.69
V. A critical consideration for design is developing products, services and systems that take account of eco-design principles such as the use of green materials, design for dismantling, and increased energy efficiency.	3.84	0.99	3.75	0.88
W. Design is "world" creation; everyone engages in design all the time. It is the oldest form of human inquiry giving rise to everything from cosmologies to tools.	4.02	0.81	4.05	0.71

X. Design, in itself, is a learning activity where a design continuously refines and expands their knowledge of design.	4.14	0.59	4.17	0.68
Y. Designers use visual representations as a means of reasoning that gives rise to ideas and helped bring about the creation of form in design.	3.83	0.61	4.03**	0.67
Z. Information is central to designing.	4.00	0.76	4.05	0.85
AA. Design is iterative.	3.33	0.78	3.83**	0.77

Students showed a change in their conceptions of design as well as in their beliefs about their abilities. Five of the statements on design changed significantly between the time of evaluation. Not surprising these incoming first year students were much more similar to the ME students of Oehlberg and Agigno than the professional engineers polled by Mosborg. One change worth noting showed up in free text responses taken after the program, "Good designers have intrinsic design ability." A number of students made written comments relating to their increased comfort in being able to accomplish design, that design is not an un-learnable art but a process that they could learn, practice and perfect.

Conclusion

The initial objectives for this program were achieved. The program was rated as "highly positive and would recommend to a friend" by 100% of the students and peer mentors that completed the post event survey (85 students and all peer mentors). The program introduced students to many of the hands-on opportunities available to them on campus.

Beyond engaging and entertaining the students, the program successfully introduced students to the engineering design process in a positive manner, teaching skills and increasing students' confidence in their abilities and success. Design Immersion participants have higher participation rates on competition design teams and clubs (e.g., SAE Formula, SAE Formula Hybrid, Student Space Sciences Research Lab, and BlueLab) than students that didn't participate in design immersion. This is likely due to heavy team recruiting by dynamic peer mentors during the program as well as an increased belief in students' own ability.

This cohort will be followed through their undergraduate degree to further understand the program impact. Separating out effects specifically due to the design immersion program will be difficult as it is the first activity in much larger four year offerings from the Center for Entrepreneurship and the Multidisciplinary Design Program. The program was renewed for 2012 when we will address weaknesses from this first test of the program.

appendix

The following is a summary:

Table 5: Timeline for Bus Stop Challenge

Step	Time	Process	Description
Step 1	3-3:20pm	Develop interview questions	Brainstorm questions you want to ask to better understand bus riders' behaviors, thoughts, and needs.
Step 2	3:20-3:40pm	Travel to first bus stop	Depart for assigned bus stop; start interviewing while on the bus.
Step 3	3:40-5:30pm	Interview and observe	Visit your (2) assigned bus stops and individually talk to students and make observations. Document in your notebook. Finish by 5pm and head back for dinner.
Step 4	5:30-6:30pm	Synthesize/brainstorm ideas over dinner	Reconvene for dinner and spend time writing and sharing most important learnings from interviews/observations. Start process of ideating solutions.
Step 5	6:30-8:00pm	Brainstorm ideas and create	Continue brainstorming ideas for concept and finalize. Once your group has agreed on a solution, use the materials provided (cardboard, markers, construction paper, string, etc.) and create a prototype or visual mock-up of your concept.
Step 6	8:00-8:30pm	Film pitch	Use the video camera provided to you (or the video camera on your phone) to film a 3 minute pitch of your concept. Upload to the multi-disciplinary design Facebook page.

Table 3: Building materials for Rub Goldberg Design Activity

1 roll duct tape	10 marbles	3 ft string	1 ping pong ball
1 pair scissors	1 hot wheels car	1 plastic spoon	10 large rubber bands and 10 small rubber bands
2 dowel rods 3 ft long	1 foam cup	1, 3 ft long piece of elastic	10 note cards

1 poster board	10 paper clips	4pencils	2 AA batteries
1 kinex motor	5 long kinex pieces		

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