AC 2009-764: USING ENGINEERING DESIGN AS A RETENTION TOOL FOR FIRST-YEAR ENGINEERING STUDENTS

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Abstract

A common first-year engineering program has a unique role in defining the future path for incoming engineering students. A long-standing benefit of such programs is to provide students with the time necessary to make an educated decision about their choice of major. Often this is the first experience in the role of engineers in society and consequently what students use to determine whether to continue pursuing an engineering degree. For students at Michigan Technological University, this decision primarily occurs during their first or second year. Therefore, the contents of the first-year engineering courses make a crucial first impression.

The first-year engineering program at Michigan Tech consists of a two course sequence that was designed to give the students the engineering skills necessary to succeed at any engineering discipline while providing the opportunity to learn more about the different majors. From 2000 to 2006, students were scheduled for their engineering courses as part of a cohort with calculus and physics. While the material covered in the first semester was common throughout the sections, the design projects for the second semester course were selected by instructor preference. In this manner, students had the potential to be enrolled in a section where they had little to no interest in the project that was chosen. In the spring of 2006, students had the opportunity to select a cohort schedule based on their preference for design project. This study will compare the student populations before and after this course modification to determine the effectiveness of specialized design projects with regard to student choice and persistence in their engineering major.

Introduction

A major benefit of a common first-year engineering program is the time available for students to make a decision regarding their choice of major. Engineering students entering Michigan Technological University (Michigan Tech) have the option of enrolling into a specific major (biomedical, chemical, civil, computer, electrical, environmental, geological, materials, or mechanical) or enrolling into the university as a general engineering student. The abbreviations used to describe the various majors can be found in Table 1. Regardless of major choice, all entering engineering students are enrolled into a cohort schedule that includes calculus, physics, and engineering classes.

Table 1. Engineering Program Abbreviations

EBE = Biomedical Engineering	EEN = Environmental Engineering
ECE = Civil Engineering	EGE = Geological Engineering
ECM = Chemical Engineering	EGN = General Engineering/Engineering Undecided
ECP = Computer Engineering	EME = Mechanical Engineering
EEE = Electrical Engineering	EMSE = Material Science and Engineering

It has been suggested that the first-year experience is important for student persistence in STEM fields.¹ The first-year engineering experience at Michigan Tech is comprised of two courses:

ENG1101 (Engineering Problem Solving and Analysis) and ENG1102 (Engineering Modeling and Design). Both courses instruct students in the skills they need to succeed in any engineering discipline, as well as investigate topics unique to the various engineering disciplines. As such, a major portion of ENG1102 is the completion of an interdisciplinary design project that focuses on bringing real-world examples into the classroom. Past students have investigated alternative fuels, autonomous robots, human-hybrid and supermileage concept vehicles, New Orleans flood management plans, microbrewery systems, and vending machines.

According to a study completed by Hertel and Hamlin on the incoming student population of fall of 2000 at Michigan Tech, only 40% of students graduated in their originally declared major with the majority of these changes occurring during the first or second year.² There are several factors that contribute to student persistence in their chosen major, one of which is self-efficacy. Women in particular have been shown to be particularly influenced by their efficacy beliefs.^{3,4,5} Self-efficacy theory suggests that mastery experiences (experiences gained by performance on particular tasks) are the most influential source of efficacy.⁶ Enjoyment, interest, and satisfaction in an experience are also influential in promoting efficacy. A strong team experience also has positive benefits toward a student's self-efficacy.³

Based on self-efficacy theory, it can be hypothesized that students having a successful experience in their first-year engineering classes, in particular their team design experience in ENG1102, should persist in their major. This has yet to be tested at our university. This study looks at the retention for students enrolled in ENG1102 during the spring 2005 and 2007 semesters, before and after a major course modification. Prior to 2006, students registered for ENG1102 in their calculus and physics cohort and had no choice in the design project selected by the instructor. After 2006, students were able to register for a spring cohort schedule with prior knowledge of the design project. With this option, they could register for a design project more of interest to their declared major.

This study looks to answer the following questions:

1. What impacts a student's choice of design project?
2. Does the design project topic significantly impact student persistence in their declared engineering major?
3. Are the persistence statistics different for women with regard to design project choice?

Sample Populations

The samples chosen for this study are the students enrolled in ENG1102 in the spring semesters of 2005 and 2007. The spring 2007 group was chosen because this year students had a choice of only one design project per section. The group chosen for comparison (spring 2005) was chosen because this was the last group to go through ENG1102 before the switch to student choice in design project and the course has not gone through major revision of course content since that time. Both these samples were tracked for three academic years to determine the major changes associated with each group.

In spring 2005, 519 students were enrolled in ENG1102. Of these students, 30 were not enrolled for the comparison timeframe after completing ENG1102 and were not included in the following statistics. Of the remaining 489 students, 452 (92%) were first-year engineering students; the

remaining 8% were upperclassmen. There were 94 students (19%) that came into the university as EGN students. Most of the students (91%) defined themselves as “White/non-Hispanic” and the population was 84% male.

Spring 2007 has a similar demographic. This population has an entering population of 511 with 37 students who were not enrolled after taking ENG1102. This group was also excluded from the comparison statistics. Of the remaining, 432 students (91%) were first-year engineering students with 21% (98 students) as EGN majors. Again, most of the students (94%) defined themselves as “White/non-Hispanic” and the population was 79% male.

The composition of the ENG1102 classes with regard to major for each group can be found in Figure 1 below. As expected, EME has the largest number of students in both groups, although 2005 had a larger population of EME students. The second largest major in both groups was EGN. It should be noted that the percent of students shown as EGN majors in Figure 1 are 15% (2005) and 26% (2007) lower than the number of students coming into the university as EGN students, as these students changed their major while enrolled in ENG1102. Enrollment of EMSE, ECE, ECM, EEE, EGE students was consistent between groups. There were a larger number of EBE and EEN students in 2007 and a smaller number of ECP students in that year as well. More surprising was the number of non-engineering majors (other) enrolled in 2007. These students were most likely engineering students enrolled in a major that grants associate degrees so they could qualify for financial aid through the State of Michigan’s Tuition Incentive Program (TIP).

Figure 1. Major Distribution in Spring 2005 and 2007 ENG1102 Classes

Design Project Selection

A study at Arizona State University concluded that activities that promote engineering self-efficacy and persistence in engineering are based on authentic (i.e. “real-world”) data.⁷ The

design projects offered in 2007 are based on real-world situations and included an autonomous robotic vehicle, human-hybrid powered vehicle, microbrewing, New Orleans flood management, and supermileage concept vehicle. Each design project had the same deliverables and required a 3D solid modeling and computer programming component. For example, microbrewing students created a solid model of the production facility and developed a program that tracks mass and energy balances through the various unit operations of the brewery. Each design project targeted several key disciplines and topics as summarized below:

- ***Autonomous Robotic Vehicle (1 section)*** topics included control programming, energy use and storage, control configuration diagrams, and mechanical design. Students design robots with the ability to sense obstacles and barriers and automatically stop or avoid them, as well as the ability to track its own location and the location of nearby objects. Key disciplines: ECP, EEE, EME
- ***Human Hybrid Vehicle (2 sections)*** topics include aerodynamics, power consumption, generation, and storage, civil infrastructure design, and logic programming. Students design a vehicle concept with a combination of human and another energy source for commuting. In each case, students also design the infrastructure necessary to ensure success of the design. Key disciplines: EBE, ECE, ECP, EEE, EMSE, EME
- ***Microbrewing (3 sections)*** topics include mass balance, fluid mechanics and pumps, process control programming, and factory layout and design. Students design a turn-key brewing line with sufficient automation to allow novice, part-time brewers to make batches of basic ale recipes. Key disciplines: ECM, EEN, EME
- ***New Orleans Flood Management (3 sections)*** topics include control programming, hydrostatic forces, weather statistics, mass balance, geologic considerations, civil infrastructure, and emergency management. Students design a sustainable flood management system that incorporates the economic, environmental and social issues of the New Orleans region.⁸ Key Disciplines: ECE, EEN, EGE
- ***Supermileage Concept Vehicle (2 sections)*** topics include aerodynamics, power consumption and generation, control programming, energy use and storage, control configuration, and mechanical design. Students design single passenger cars to run on a simulated test track against other SMV designs. Key disciplines: EBE, ECP, EEE, EMSE, EME

A survey was run on the spring 2009 semester ENG1102 students as to why they chose a particular section of ENG1102 and it is hoped that these results would be consistent with prior years. The results are indicated in Figure 2 below. As shown, the time of class affected the decision of approximately 29% of the students. This could be students choosing a later design project rather than an 8:00 am class, or based on free time between other scheduled classes. The design project influenced the choice of ENG1102 section for 64% of the students, with 30% of the students responding that their choice was based solely on the design project and 34% that reported their choice was based on a combination of factors with the design project being amongst them. This indicates that often students had a tradeoff between course times and design project choices as well as other factors. Very few students (3%) chose a section of ENG1102 based solely on friends that were also enrolled in that section which indicates that, for the majority of students, this is an individual decision.

Figure 2. Reasons for ENG1102 Class Selection (Spring 2009)

With these things in mind, and barring no course conflicts, it was expected that the students would register for ENG1102 according to the design projects targeting their chosen major. The EGN students would be expected to populate according to the most available sections. If we estimate registration based solely on the amount of sections offered in each topic, the projected enrollment would be as follows: microbrewing – 27.3%, New Orleans flood – 27.3%, human-hybrid vehicle – 18.2%, supermileage vehicle – 18.2%, autonomous robot – 9%. The actual registration profile for the various majors for 2007 is shown in Figure 3 on the next page. As expected, the EGN students register approximately as predicted. The ECE and EME students also register very similarly. It was expected that ECE students would register primarily for the New Orleans flood and hybrid-human vehicle projects due to the infrastructure design inherent in each project, but this was not the case.

Microbrewing was predicted to be most popular with ECM majors, but due to a scheduling conflict with a required chemistry course, a large number of ECM students were unable to register for that section. Overall, microbrewing appears to be the most popular topic, having a diverse population and appears to be a significant choice for ECP, EEE, and non-engineering majors. This may be due to the communal interest in beer that many students share as well as the number of sections offering this design project.

As expected, EBE majors gravitated toward the supermileage vehicle design, but also the autonomous robot as well. EEN students also registered for the supermileage project frequently, most likely due to the potential for reductions in fossil fuel dependency with a large mpg vehicle. The New Orleans flood project was also popular for EEN majors as predicted. ECM and ECP students also gravitated toward this project most likely due to the number of available sections.

Figure 3. Population of ENG1102 Design Projects by Engineering Major

EMSE and EGE had a small number of declared students (6 and 4) respectively so it is difficult to draw specific conclusions from such a small sample. Based on the section choices that did occur and self-efficacy theory, it is expected that students who are enrolled in a design project applicable to their major will be more likely to persist in that major.

The projects selected by men and women differ. As shown in Figure 4, the most popular design project selected by women was the New Orleans Flood Project, with 28% of the women selecting this project. On the other hand, the most popular design project for the men was microbrewing with 33% of the men selecting this project. The two projects selected more frequently by percent women than percent men are the flood and robot projects.

Figure 4: Selected Design Project Population by Gender

Data Analysis

Table 2 summarizes the major changes that were made by the spring 2005 comparison group. Of the 489 students in the comparison group that were enrolled at Michigan Tech after taking ENG1102, 81 were enrolled as EGN. It is expected that students who initially enroll in this major, will change their major. As shown in Table 2, more than 50 % of the students changing their major in their first two years are due to migration of general engineering students into degree granting majors. Of the students who changed their majors, most of them switched to a major within the College of Engineering (50-88%), while between 10% and 33% of the students switched to a major within the School of Technology and up to 29% switched to a major outside the College of Engineering and School of Technology. Additionally, during each semester there were students who were not enrolled. For this study, these students were gone for one or more semesters during the first two years of the study period. These students may have been completing a co-op or study abroad experience, or they may have been suspended or left the university.

The number of major changes that were made by the students enrolled in ENG1102 during the spring of 2007 are shown in Table 3. The number of major changes due to EGN students migrating to degree granting programs is 75 and 64% during the 2nd and 3rd semesters and drops

off from 35% for the 4th semester to 10% during the 6th semester. As in the comparison group, the majority of major changes (up to 88%) are made within the College of Engineering, while between 5 and 20% change into the School of Technology, and up to 38% of the major changes within a semester are to programs outside the College of Engineering or School of Technology.

Table 2. Spring 2005 Data – Major switches 2nd – 6th semesters.

Semester	2 nd	3 rd	4 th	5 th	6 th
# of Major Switches	25	84	32	38	18
Into ENG	22	64	21	24	9
EUN switch	13	46	18	12	3
Out to technology	3	8	4	3	3
Out of ENG	0	12	7	11	6
# Not Enrolled	12	3	15	35	41

Table 3. Spring 2007 Data – Major switches 2nd – 6th semesters.

Semester	2 nd	3 rd	4 th	5 th	6 th
Major Switch	33	75	26	16	10
Into ENG	29	63	22	9	7
EUN switch	25	48	9	4	1
Out to technology	4	4	2	1	2
Out of ENG	0	8	2	6	2
# Not Enrolled	4	7	24	42	55

The number of major changes made during each semester for both study groups are compared in Figure 5. While there are more students in the 2005 study group (2005, n=489; 2007, n=474) and more major changes (197 compared to 162), there are more changes for the 2007 study group occurring at the beginning of the students 2nd semester, the semester they were enrolled in ENG1102. This could be due to an increased push by the EGN advisors that year to get students to change their major earlier if they were ready. This was done so the EGN students were not at a disadvantage when registering for major specific courses. In general, it appears that the students making major changes in the 2007 study group are changing their major earlier than the students in the 2005 study group.

Figure 5. Number of Major Changes for each Semester

Table 4 below summarizes the persistence of the students in their declared major as they enter ENG1102 in the spring of 2005 and 2007. This data looks at all the first-year engineering students enrolled in ENG1102 in the spring 2005 and 2007 semesters. As expected, the percent of Engineering Undecided (EGN) students retained in their original major is close to zero for both study groups, which reflects the fact that these students are switching into a degree granting major. More than 57% of the students are still in their originally declared engineering major at the end of their third year, with most of the majors retaining between 75 and 85% of their original students. With the exception of EGE, EME, EMSE, and non-engineering majors, the percent of students retained in their original major is lower for the students in 2007 than in 2005. Overall, 90% and 87% of students who were enrolled in ENG1102 during the spring of 2005 and 2007, respectively, were still enrolled at Michigan Tech at the end of the 3 year study period, while 86% (2005 students) and 83% (2007 students) were still enrolled in the College of Engineering. As shown in Table 5, the women who were enrolled in ENG1102 were retained at Michigan Tech and in the College of Engineering at similar rates over the three year study period.

Table 4. Persistence of Students by Engineering Major Enrolled in ENG1102 Spring 2005 and 2007 Semesters

Major	ENG1102 2005			ENG1102 2007		
	Original Distribution	Final Distribution	% of Initial Students	Original Distribution	Final Distribution	% of Initial Students
EBE	31	29	81	43	43	77
ECE	40	51	83	45	58	78
ECM	48	47	85	51	43	78
ECP	39	27	64	30	19	57
EEE	41	52	85	44	43	73
EEN	5	10	100	16	14	75
EGE	2	3	100	3	5	100
EGN	85	5	0	73	1	3
EME	165	147	75	136	124	82
EMSE	10	16	60	10	10	60
Other:	21	50	5	11	25	36

Table 5. Retention of Students Enrolled in ENG1102 over the 3 year study periods.

	2005 Study Group		2007 Study Group	
	All Students	Women	All Students	Women
Number of Students		78		101
Retained in Engineering for 3 yrs	(86%)	65 (83%)	(83%)	85 (84%)
Retained at MTU for 3 yrs	(90%)	74 (95%)	(87%)	91 (90%)

One thing to investigate is the number of students making changes to their major. In the ENG1102 2005 group, there were 142 students making one change (31%) and 18 making 2 or more changes (4%). Compared with the 2007 group, 125 students with one change (29%) and 12 making 2 or more (3%), the numbers are fairly consistent. For both groups, the most popular major switches seem to be out of ECP and EMSE. There appears to be a significant positive migration into ECE, EEE, and non-engineering majors. This is consistent with the results from

the 2000 study. From this, it can be expected that a common migration path for the ECP students would be into EEE, which would explain their respective results.²

Figure 6 looks at the persistence in engineering major compared to enrollment in the various design projects. It is expected that students enrolled in projects relevant to their chosen majors will persist at a higher percentage than those enrolled in other sections of ENG1102. To reduce bias, persistence in the majors will only be compared with design projects of approximately equal enrollment. EEN, EGE, and EMSE had too small of a population to compare in the different sections and are not included in this analysis.

Microbrewing and the human-hybrid powered vehicle (HPV) had the same number of EBE students enrolled in these sections. Because the HPV project had EBE as a key discipline, it would be expected that the students enrolled in this section would persist at a higher rate than the students in microbrewing. This was indeed the case as students persisted at 100% in the HPV sections versus 75% in the microbrewing sections. EBE students in the flood and robot sections persist equally at 88%. Neither of these projects was geared toward this major. EBE students enrolled in the supermileage vehicle (SMV) project had a persistence of 71%.

The flood project was designed with ECE as a target discipline and students enrolled in that section were retained 100%. ECE registered similarly in the microbrewing and SMV sections where the persistence was 73% and 77% respectively.

ECM students enrolled in the microbrewing project showed higher persistence as compared to ECM students taking the SMV project (90% versus 82% respectively).

The HPV, SMV, and robot projects targeted ECP students, but there was not a significant population of ECP students in these projects, so no conclusions can be drawn from them. All of the ENG1102 projects did have a computer programming aspect, and a large portion of the students registered for microbrewing (44%) and flood (33%). The persistence of the ECP students in these projects was 58% (microbrewing) and 78% (flood). As mentioned previously, the ECP students had a significant negative migration from their major.

The projects targeted for EEE majors were the robot, SMV, and HPV. Students persisted at 75%, 100% and 83% respectively. The interesting thing here was that the flood project for EEE showed a persistence of 86%. This was higher than the HPV project, which had a similar enrollment (7 students in the HPV and flood sections). As this comparison group is small, it is difficult to determine the significance of this result. A large percent of EEE (45%) were enrolled in the microbrewing project and showed a persistence of 65%. On average of the target projects, EEE students persisted 87%, which is similar to the flood project.

The last group analyzed was EME. Target projects were HPV, microbrewing, robot, and SMV. The comparison groups will be microbrewing versus SMV and flood versus HPV as they have similar EME populations. As expected the SMV group showed a higher persistence (89% versus 79% for microbrewing) and the HPV group had a higher persistence as well (96% versus 86% for flood).

Figure 6. Persistence of Students in Engineering Majors corresponding to ENG1102 design project section for spring 2007 semester

In general, the results were as expected: students enrolled in projects relevant to their chosen majors persisted at a higher rate than those enrolled in other sections of ENG1102. The HPV project showed a strong persistence in the target disciplines of EBE, EEE, and EME. Of the

ECM majors enrolled in the microbrewing project, 90% persisted in this discipline for the duration of this study. ECE majors showed a strong persistence when enrolled in the flood sections and EME majors persist at a high rate when enrolled in the SMV project.

Conclusions

In the first-year engineering program at Michigan Tech students now have the choice to register for a second semester engineering class based on the design project in that section. The results from this analysis seem to support self-efficacy theory. The ENG1102 students enrolled in a team-oriented, real-world project applicable to their chosen major are more likely to persist in their major as compared to students in a project outside of their discipline. As the sample size is small for many of the disciplines, (EEN, EGE, and EMSE in particular), it is recommended that the study be repeated for several years to get a sample size large enough to draw specific conclusions for these majors.

For a majority of the students, design project and class time are the top criteria in their decision making process when registering for a section of ENG1102. To increase students ability to register for their section of their choice, more effort must be made to avoid conflicting courses required for those majors.

It is evident that the design projects chosen by women are a different proportion than their male counterparts. Persistence of women in engineering appears to be comparable to men. With the low enrollment of women in engineering, it is difficult to form concrete conclusions as to the impact of design project choice on their persistence in an engineering major.

Bibliography

1. Menez, G., Trent D. Buskirk, Sharon Lohr, and Susan Haag. "Factors Associated With Persistence in Science and Engineering Majors: An Exploratory Study Using Classification Trees and Random Forests." *Journal of Engineering Education*. January 2008 pg 57-68.
2. Hertel, James E. and Amy J. Hamlin. "Observing Student Migration between Engineering Majors" *Proceedings of the 2007 ASEE North Midwest Conference*. Houghton, MI September 20-22, 2007.
3. Hutchinson, Mica A., Deborah K. Follman, Melissa Sumpter, and George M. Bodner. "Factors Influencing the Self-Efficacy Beliefs of First-Year Engineering Students." *Journal of Engineering Education*. January 2006. Pg. 39-47.
4. Marra, Rose M., Kelly A. Rodgers, Demei Shen, and Barabara Bogue. "Women Engineering Students and Self-Efficacy: A Multi-Year, Multi-Institution Study of Women Engineering Student Self-Efficacy." *Journal of Engineering Education*. January 2009 pg 27-38.
5. Marra, Rose M., Mieke Schuurman, Cherith Moore, and Barabara Bogue. "Women Engineering Students' Self-Efficacy Beliefs – The Longitudinal Picture." *Proceedings of the 2005 American Society for Engineering Education Annual Conference and Exposition*, Portland, Oregon. June 12-15, 2005
6. Bandura, A., *Social Foundations of Thought and Action: A Social Cognitive Theory*, Englewood Cliffs, N.J.: Prentice-Hall, 1986.
7. Yasar, Senay, Dale Baker, Stephen Krause, and Chell Roberts. "In Her Shoes: How Team Interactions Affect Engineering Self-Efficacy." *Proceedings of the 2007 American Society for Engineering Education Annual Conference and Exposition*, Honolulu, Hawaii. June 24-27, 2007

8. Kemppainen, Amber J., Alex S. Mayer and Jacqueline E. Huntoon. "Introducing Sustainable Design into First Year Engineering Education" *Proceedings of the 2007 ASEE North Midwest Conference*, Houghton, MI. September 20-22, 2007.