Confidence of Undecided First-Year Engineering Students in Choosing Their Major and Implications for Retention

Ashley Evanoski-Cole, Colorado State University

Ashley Evanoski-Cole is a Graduate Research Assistant in the Department of Atmospheric Science within the College of Engineering at Colorado State University. With a B.S. in Chemistry and a M.S. in Atmospheric Science, she is currently pursuing her Ph.D. in Atmospheric Science. She studies anthropogenic impacts on air quality, focusing on emissions from oil and gas extraction. Her educational research has focused on understanding first-year student confidence in STEM and impacts on retention.

Dr. Kimberly Catton P.E., Colorado State University

Professor of Practice Mechanical Engineering

Mr. Bert Vermeulen, Colorado State University

Bert Vermeulen earned bachelors and masters degrees in mechanical engineering from the Massachusetts Institute of Technology and a masters degree in business from Stanford University. He has been teaching engineering design classes and introductory engineering classes at Colorado State University since 2009. Prior to teaching, Bert had over 20 years of practical industry experience in engineering, management, and entrepreneurship. His courses are focused on providing practical hands-on engineering experience. In addition to teaching classes to native English speakers, he has also taught special introductory engineering classes for foreign students who do not have English as their primary language.

Mr. Jamison Taylor Bair , Colorado State University

Jamison Bair is a Graduate Student pursuing a Masters of Science in Mechanical Engineering at Colorado State University. He received his BS in Mechanical Engineering from Colorado State University in May 2016. Jamison is one of the GTAs for MECH-468, the senior design capstone class at CSU. He is also the Project Manager for the CSU Vehicle Innovation Team competing in the intercollegiate automotive engineering competition EcoCAR3 and the President of the CSU Student Chapter of the Society for the Advancement of Material and Process Engineering (SAMPE). His areas of research include manufacturing education, advanced composite material structure design and manufacturing, and design and assembly of energy storage systems. He most recently completed an internship at Tesla Motors and hopes to work in the transportation or renewable energy industry after completing his MS.

Dr. Thomas H. Bradley, Colorado State University

Thomas H. Bradley is an Associate Professor of Mechanical Engineering in the College of Engineering at Colorado State University, where he conducts research and teaches a variety of courses in analysis, design and policy for sustainable energy systems. In 2013, Bradley was awarded the Ralph R. Teetor Award for Excellence in Engineering Education and the US Dept of Energy EcoCAR2 Outstanding Incoming Faculty Advisor Award.

Confidence of Undecided First-Year Engineering Students in Choosing Their Major and Implications for Retention

Abstract

Freshman students often start college with uncertainties about what major they want to study. This research presents student survey data that were collected in a project-based introductory engineering class at Colorado State University where students have enrolled in the College of Engineering but are undecided on a specific discipline to study. Surveys were administered to the students in this class to measure their experiences, attitudes, interests, and confidence to understand what factors influenced their decision in choosing a major and how that impacted retention in the College of Engineering. Engineering degrees require a strong foundation in math, chemistry, and physics, and these courses generally make up the majority of a first-year engineering student's class schedule. However, some freshman students are uncertain about their abilities in math and science. Confidence can be an important factor in students who are not retained in engineering programs. In this introductory engineering class, a variety of activities and opportunities were provided to the students to gain a broad sense of what is involved in being an engineer and to learn about the specific engineering disciplines. Additional university or department resources were available to the engineering students to help with math, chemistry, physics, or engineering classes, which included tutoring or extra help sessions. This study investigates how the different activities and resources both inside and outside of the introductory engineering course impact how students decide their engineering discipline and their confidence in their decision. At the beginning of the semester, only 15% of the total class and 0% of female students were very confident in their decision of what engineering discipline they wanted to study. As the semester progressed, survey data indicated that student's confidence levels in picking their engineering major did not change significantly even though the majority of students did choose a major by the end of the semester. Students tended to view math, physics, and chemistry as being more challenging by the end of the semester with no significant trends found in student confidence in these subjects. According to student surveys, at the beginning of the semester over 67% of the class identified math, chemistry, and physics as being challenging subjects versus over 82% by the end of the semester. This preliminary study can be used to further develop resources to help first-year undecided engineering students confidently choose their course of undergraduate study which could lead to an improvement in retention.

Introduction

The majority of students not retained in engineering or other STEM fields, either leaving the program or dropping out of college entirely, leave during their first-year.[1–3] Previous studies have shown that students who leave engineering are often in good academic standing and that there are many important non-cognitive characteristics of students who decide to leave engineering.[4–7] Attitude and self-confidence have been reported as two of the many factors important for understanding and predicting engineering student retention.[1,8,9] Longitudinal studies that investigated how student confidence changes throughout their time in engineering programs have shown that student confidence is lowest during their first year[6,10] and is lower among female engineering students.[11,12] Student performance and attitudes towards the engineering core courses of math, physics, and chemistry are also important in understanding student retention.[6,13] Confidence in math and science has been identified as one of the most important factors in first-year students who are retained in engineering.[5,14]

In addition to the many factors influencing students to persist in engineering, there are also numerous and often overlapping factors that affect a student's decision of what engineering major to study. Students will be more likely to choose a STEM major if they have higher confidence in their academic abilities.[15] In particular, it has been long known that self-confidence and self-efficacy in math is an important factor in choosing and persisting in a STEM major.[15–17] In this study, we explore the confidence of undecided engineering students in their choice of engineering major by investigating the impacts of student attitudes and confidence towards first-year math, science, and engineering courses. The impact on their retention during their first semester is also investigated.

At Colorado State University, an average retention rate for freshman engineering students from the fall to spring semesters is 55.0% (Table 1). Freshman students just starting their college education can be uncertain about what they would like to study and how those areas of study will impact their future career path. Even students who choose to study engineering are faced with the question of what specific engineering major to study and often do not know enough about each discipline to make an informed and confident decision. At Colorado State University, 8-18% of incoming engineering students are undecided on which engineering discipline they want to pursue and register as "Open Option" students (Table 1).

Table 1: Five years of enrollment data for freshman engineering students at Colorado State University showing retention for all freshman engineering students from the fall to spring semesters and the percent of students registered as "Open Option".[18]

	Engineering Enrollment		Retention (%)	Open Option Students (%)	
Year	*Fall*	*Spring*		*Fall*	*Spring*
2015-2016	604	349	57.8	8.4	5.4
2014-2015	518	237	45.8	14.7	9.3
2013-2014	577	318	55.1	14.0	4.7
2012-2013	615	368	59.8	17.6	10.3
2011-2012	495	279	56.4	16.2	10.0
Average	562	310	55.0	14.2	6.9

Methods

This study focused on survey data from Colorado State University students taking the Grand Challenges in Engineering course, a 100-level course designed primarily for first semester freshman students who want to major in engineering but are unsure which branch of engineering they would like to study. Of the 52 students in the class, 4% were enrolled in a specific engineering major, 69% were Open Option engineering students, and 27% were in Engineering Science. Open Option students are in the engineering department but have not yet chosen a major. Engineering Science includes students who want to study space engineering, engineering education, or engineering physics.

Race and gender of the class (n=45) are shown in Figure 1. Non-traditional students in this course included 11% first generation students, 4% NCAA athletes, 7% self-identified as having a mental health issue, and 4% self-identified as having a learning disability. According to university registration data, 38% of the students were taking a pre-calculus course, 60% were taking Calculus I or higher, and 2% were not enrolled in any math course. Additionally, 58% of the class was in the required 100 level chemistry class and 4% were in the required physics course for engineers.

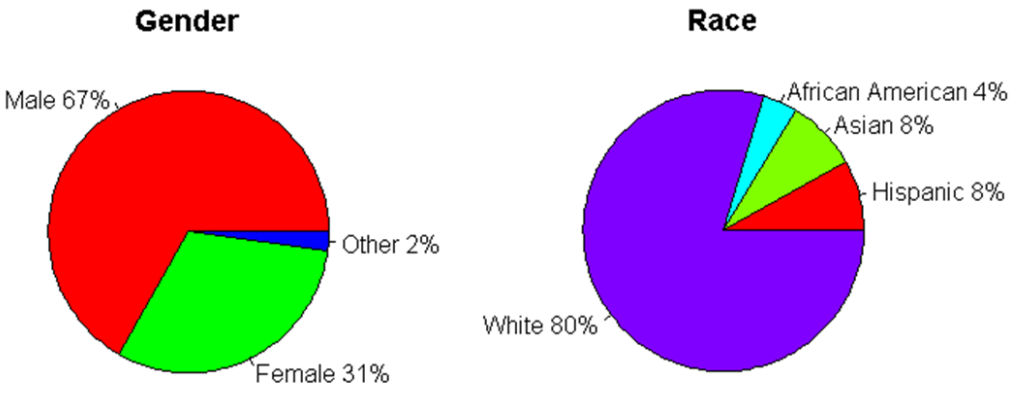

Figure 1: Demographic data for freshman engineering students who participated in this study.

A series of four surveys were administered to the students in this 15-week course during weeks 4, 8, 10, and 15. The survey questions and response choices, summarized in Table 2, used a four- or five-point Likert scale. Four measures were investigated which is also described in Table 2. Additionally, open-ended questions were asked at the end of the semester to obtain comments on student attitudes and thoughts on their likelihood of staying in the engineering program.

Table 2: For the four surveys administered throughout the student's first semester, the four different measures, survey questions, and summary of survey responses are listed.

Measure	**Survey Question**	**Survey Responses**
1. Confidence, interest level and value of engineering core courses	1) Do you think [chemistry, math, or physics] is interesting? 2) Do you think [chemistry, math, or physics] is important for engineering? 2) Do you think [chemistry, math, or physics] is challenging?	5 – Strongly Agree 1 – Strongly Disagree
2. Importance of various factors that impact confidence in engineering core courses	Did participating in these different activities this semester improve or hurt your confidence in [chemistry, math, or physics]?	5 – Significantly improved my confidence 1 – Significantly hurt my confidence
3. Confidence in deciding what engineering major to enroll in	How confident are you in your decision to study that specific engineering discipline?	4 – Very Confident 1 – Not Confident
4. Importance of various factors in deciding engineering major	In your current decision of major and/or concentration, please indicate how important each of these factors were in helping make your decision.	4 – Very Important 1 – Absolutely No Impact

A series of questions administered throughout the semester were given to assess how confident students were in deciding what engineering major they wanted to study. Students were also asked to assess what factors were important in their decision of engineering major. In their engineering class, students were provided multiple opportunities to learn about the different branches of engineering. Fifteen guest lecturers of various engineering backgrounds visited the class throughout the semester ranging from graduate students to engineers in industry which are summarized in Table 3. The students were presented with multiple present day engineering problems during class lectures from the Engineering Grand Challenges (http://www.engineeringchallenges.org/). Two student-picked challenges, Providing Access to Clean Water and Make Solar Energy Economical, were covered in greater depth. Finally, students also completed a semester long group project based on an Engineers Without Borders (EWB) Challenge that focused on mastering the engineering design process and effectively working as a team (http://www.ewbchallenge.org/unhcr-zambia). Outside of class, student experience and their attitudes towards their engineering core courses were considered. Student participation in these courses, attendance at office hours or tutoring, and completion of homework assignments were also assessed as factors that impacted their decision of engineering major. Several non-parametric statistical tests appropriate for small ordinal datasets with no assumption of normality were used in this analysis. The Mann-Whitney test was used to determine statistical differences between survey parameters and the Friedman test was used to find statistical differences in the same question between different surveys to investigate trends in the survey data at the 95% confidence level.

Table 3: A summary of the guest lecture schedule, topics discussed, and relevant types of engineering represented.

Week	Guest Lecturer Topic	Engineering Branches Highlighted
1	Bridges, Infrastructure	Civil
3	Bridges	Civil
5	Rockets, Engine Combustion	Mechanical, Space Engineering
5	Clean Water Technologies	Civil, Environmental, Chemical
6	Clean Water, Improved Cookstoves	Environmental, Mechanical
7	Solar Energy	Mechanical, Environmental
9	Biofuels	Chemical, Environmental
11	Modeling Joint Motion	Biomedical, Mechanical
11	Biofuels and Bioengineering	Chemical, Biological
11	Developing Hydrogels	Chemical, Materials
11	Modeling Frame Structures	Civil
11	Algorithm Optimization	Electrical, Computer
11	Biomechanics of Muscle	Mechanical, Biomedical
12	Prosthetics	Biomedical, Mechanical
13	Antennas	Mechanical, Electrical

Results and Discussion

In each of the four surveys administered in the Grand Challenges in Engineering course, the attitudes of students towards chemistry, math, and physics were measured using the responses described for Measure 1 in Table 1. No statistical differences were found in how student attitudes towards the importance of physics and math in engineering changed during the semester, but views on the importance of chemistry in engineering (χ^2=9.5, df=3, p=0.024) and interest in chemistry (χ^2=9.8, df=3, p=0.020) increased, determined using the Friedman test. Averaging across all surveys, the most significant statistical difference was that student's viewed math as more important than chemistry for engineering (W=2842, p<0.000), determined using the Mann-Whitney test (Table 4).

Table 4: The average and standard deviation of all survey responses assessing student attitudes towards chemistry, math, and physics.

	Chemistry	**Physics**	**Math**
Interesting	3.6±0.9	4.1±0.6	4.0±0.8
Important	4.1±0.6	4.5±0.5	4.8±0.5
Challenging	4.1±0.8	4.1±0.7	4.1±0.7

Different trends were observed in how challenging the students thought the core course subjects were. Throughout the semester, the differences in student attitudes towards how challenging they viewed chemistry (χ^2=14.06, df=3, p=0.0028), physics (χ^2=9.50, df=3, p=0.023) and math (χ^2=7.82, df=3, p=0.05) were found to be statistically different (Figure 2). Students found chemistry, math, and physics to be more challenging at the end of the semester compared to the beginning of the semester. It is hypothesized that throughout the first semester, participation in the engineering course, math, and chemistry classes allowed students gain a better understanding of what each subject entailed. End of semester student comments such as "I was not expecting the amount of homework I have" and "It is a lot more homework than what I was expecting" suggest that some students struggled with the transition from high school to college level classes.

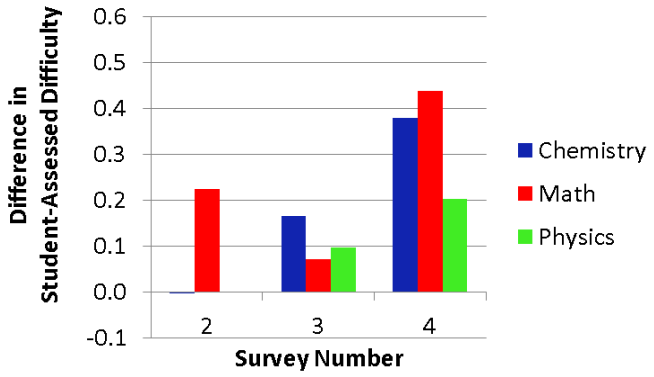

Figure 2: The differences in student-assessed difficulty of chemistry (blue), math (red) and physics (green) throughout the semester compared to the first survey.

Student confidence in chemistry, math, and physics was also considered as described for Measure 2 in Table 1. In the final survey, students were asked if different factors improved or hurt their confidence in each core subject. Here we focus on math and chemistry, since the vast majority of students in this engineering course (96%) were not concurrently taking a physics class. For the engineering students taking general chemistry, they were asked to rate how each of the following factors impacted their confidence in chemistry: going to class, going to office hours or tutoring, completing electronic homework, or completing homework in an online personalized learning program. To understand what factors impacted students taking math classes, the engineering students were split into two groups: students taking calculus or a higher level math course and students taking a pre-calculus course. The pre-calculus courses are offered online in a series of modules specific to the needs of the student. The factors of attending class and participating in office hours or tutoring were also considered to understand what impacts student confidence in math. On average, students rated going to office hours as being a more positive impact on confidence compared to online homework or online personalized learning exercises for chemistry. Similarly, students rated office hours more favorably than online instruction for improving confidence in math. The only statistical difference was observed in how students viewed attending a traditional class compared to participating in online instruction. Students rated attending a traditional class as more favorable that the online course ($W=253.5$, $p=0.042$). This suggests that person to person interactions such as office hours and tutoring helps student confidence more significantly than online instruction or individual online homework assignments.

Table 5: The average and standard deviation of the importance of various factors that impacted the confidence of students in math and chemistry classes.

Class	Factor	Average Importance
Chemistry	Attendance in Class	3.8±1.1
	Completion of Online Homework	3.4±1.2
	Completion of Personalized Learning Homework	3.7±1.3
	Attendance at Office Hours or Tutoring	3.8±0.7
Math	Attendance in Class	4.1±0.7
	Attendance in Online Class	3.5±1.0
	Attendance at Office Hours or Tutoring	4.1±0.7

Finally, students were asked to report their confidence level on their choice of the specific engineering major they either wanted to pursue or had already registered for as investigated in Measure 3 of the survey (Table 1). Since some first-year students do not have a clear understanding of what different types of engineering entail, our hypothesis was that student confidence in determining their major would increase as they learned about and interacted with different types of engineers. However, no statistically significant trends were found in the changes in the student's confidence in choosing an engineering discipline (Figure 3).

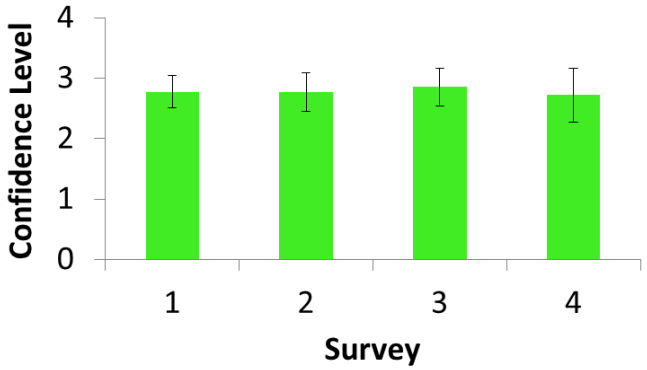

Figure 3: Self-reported student confidence in choosing an engineering major assessed in surveys administered throughout the first semester. The error bars represent the 95% confidence interval.

Addressing Measure 4 of the survey (Table 1), the importance of guest lecturers, the Engineers without Borders project work (EWB), discussion of the engineering grand challenges or participation in the chemistry or math classes in student's decisions of engineering major were explored. No statistically significant trends in any factors were found throughout the semester (Figure 4). For students declared "Open Option" in engineering, no statistical difference in confidence levels for the first three surveys were found. Even as confidence levels did not change, the median student response of three indicates that the majority of students found each

factor to be either somewhat or very important to making their decision on which engineering major to study. Additionally, many Open Option students chose majors by the end of the semester. The amount of Open Option students decreased from 69% to 14% from the beginning to the end of the semester, according to enrollment data.

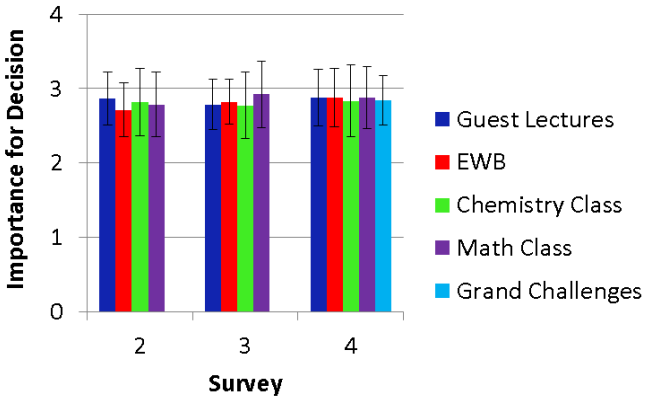

Figure 4: The student ratings on the importance of various factors for undecided students choosing their major. Guest lectures, Engineers Without Borders project (EWB), and attending chemistry and math classes were assessed in surveys 2, 3, and 4. Only survey 4 assessed the impact of students learning about the Engineering Grand Challenges. The error bars represent the 95% confidence interval.

At the end of the semester, using enrollment data from the upcoming semester, 10% of students from this course were not enrolled as students in the university, 8% of students were enrolled in a major other outside of engineering, 14% of students were still undecided Open Option students, and 69% were enrolled in a specific engineering major. Considering this group of students who left the engineering program, only 44% of these students did not meet the math requirements upon admission to the engineering program at Colorado State University and were enrolled in a pre-calculus course. Conversely, 38% of students retained in engineering were enrolled in the same pre-calculus course, suggesting that aptitude in math and retention in engineering is not a strong predictor of retention of first-year engineering students. This supports findings from previous studies suggesting that academic performance is not the best predictor of engineering retention.[4–7]

Of the students who participated in the final survey, 13% declared they wanted to switch to a major outside of engineering and 18% were unsure if they wanted to stay in engineering. Half of the students who were unsure cited uncertainty in being able to complete the degree because of challenging subjects such as physics or not having enough dedication to finish (n=3), providing comments such as “I want to stay in engineering but sometimes I think I'm not cut out for engineering.” Other students who were unsure commented on not finding the subject of engineering interesting or enjoyable (n=1) or who found other interests (n=2). Students who wanted to switch majors (n=4) offered similar comments which included not finding the major

interesting, being too hard, not enjoying it, and not being what they envisioned engineering to be. Students who wanted to stay in engineering also provided comments of uncertainty when asked to offer their reservations in sticking with the program. Half of the comments (n=15) included uncertainty, lack of confidence or even fear of the difficulty of earning an engineering degree. Some comments pointed directly to lower confidence, such as "I'm terrified that I won't be smart enough to finish the degree" or "I feel like I'm behind the curve." Some students also expressed anxiety towards completing their engineering degree, such as "I'm afraid I won't be able to keep up or handle the stress." These comments point to the need to understand student confidence levels and provide more support and opportunities for students to improve their confidence in engineering in order to increase retention.

Conclusions

In this study, survey data collected during a first-year engineering course designed for undecided students showed significant trends in student attitudes towards the required math, chemistry, and physics classes throughout the semester. Students viewed math as being more important to engineering than chemistry, which reflects the emphasis placed on a strong math foundation to be successful in studying engineering. Students found math, chemistry and physics more challenging at the end of the semester than at the beginning. This trend may suggest that student perceptions of course difficulty change during their first semester as they adjust to college level classes and gain a better understanding of the course material needed to become an engineer. While the small sample size of this study prevents the generalization of these data to other institutions, the results did support findings in other studies. Even as the first-year students in this study were presented with information describing the different branches of engineering, student confidence in their choice of major did not increase throughout the semester. This lack of a trend in confidence is supported by a similar research study which measured no statistical increase in student confidence level in choosing an engineering major during the first semester at a large land grant university[19] similar to Colorado State University. However, course activities and material covered in the introductory engineering class and participation in math and chemistry classes did have a positive impact on helping students decide their major. Student confidence in math and chemistry was generally improved by participation in class, office hours or tutoring and not as influenced by individual homework assignments or online courses. Finally, many students at the end of the semester still expressed feelings of uncertainty and anxiety in completing their engineering degree, motivating the continued need for research to better understand student confidence and how that will impact student retention.