Impact of hands-on first year course on student knowledge of and interest in engineering disciplines

Dr. Lynn K Byers, Quinnipiac University

Lynn Byers is a Professor of Mechanical Engineering at Quinnipiac University and previously taught at the United States Military Academy. She graduated from West Point in 1987 with a Bachelor of Science in Mechanical Engineering. She earned a Master of Science and Ph.D. in Aerospace Engineering from The Pennsylvania State University in 1997 and 2006, respectively. She has taught courses in aeronautics, dynamics, vibrations, computer-aided design, thermal-fluid systems, and aerospace and mechanical engineering design. She is a licensed Professional Engineer and is a rated pilot in both rotary and fixed wing aircraft.

Dr. Justin W. Kile, Quinnipiac University

Dr. Kile is the associate dean of engineering and an associate professor of industrial engineering at Quinnipiac University. Prior to joining Quinnipiac in 2012, he was an associate professor and program coordinator for the Industrial Engineering program at the University of Wisconsin – Platteville. His research interests include material handling, facilities planning, and logistics. Additionally his education based research is in the areas of communication skills and lean curriculum development. He earned his Ph.D. and M.S. degrees from the Industrial and Operations Engineering department at the University of Michigan and a B.S. in Industrial and Manufacturing Engineering from Rochester Institute of Technology.

Prof. Corey Kiassat, Quinnipiac University

Corey Kiassat is an Assistant Professor of Industrial Engineering at Quinnipiac University, in Hamden, Connecticut. He holds a PhD in Industrial Engineering (University of Toronto), with a focus on the role of people on performance of systems. Corey has 11 years of industry experience in manufacturing engineering and operations management with General Motors. Prior to his industry experience, he completed an MBA (York University), majoring in Marketing and International Business.

Impact of hands-on first year course on student knowledge of and interest in engineering disciplines

Abstract

This paper is the first in a longitudinal study that will correlate student success with the student's initial knowledge and interest in his/her chosen engineering major. Success has two facets. For the students, success can be determined by their satisfaction with their choice of major and timely graduation. For the university, success is determined by retention of the students for the program duration. This particular paper focuses on a hands-on, introductory engineering course mandatory for all incoming engineering students. The course provides career and technical information on the four engineering disciplines offered at Quinnipiac University. The following four questions are investigated: Is there a correlation between a student's initial desire to pursue a specific engineering major and their actual and perceived knowledge of that engineering discipline? For those students who are interested in and knowledgeable about a specific engineering discipline, does the introductory course strengthen that interest? For those students who are unsure about what specific engineering discipline to choose, are the students more likely to be interested in a specific engineering discipline at the end of the course? Does the introductory course increase students' knowledge, actual and perceived, about the specific engineering disciplines? A pre- and post-course survey evaluates student interests and knowledge in each of the four disciplines. The analysis of survey results is the first step of the longitudinal study. Few statistically significant conclusions can be drawn at this point due to the relatively small sample size in each of the four disciplines. However, the work presented in this paper is valuable as a result of the framework presented and the preliminary analysis.

Introduction

Student retention in engineering programs has been studied for many years. The focus of such studies has varied from the personal characteristics the students bring with them to college to the impact of their experience in college. Early research revealed that the personal characteristics of students entering college, such as high school GPA, SAT scores, demographics, as well as attitudes and personalities, play a factor in student retention in college in general.[1,2,3] Later research focused on these characteristics specifically related to engineering retention.[4] Other studies have investigated the role that the students' college experiences have on their retention. These studies found that there were two factors at play in retention. The first was academic, which included poor teaching and advising and curriculum difficulty. The second was a feeling of lack of belonging in engineering.[5,6]

In part to facilitate retention, many colleges offer a first year engineering course.[7] Most are designed to be an active, hands-on learning environment that develop a sense of community and peer support network, which can overcome that feeling of a lack of belonging. With quality instruction, faculty mentoring, and instructor accessibility, the issues of poor teaching and advising can be overcome as well.

Quinnipiac University offers majors in four engineering disciplines: civil, industrial, mechanical and software. A course common to all engineering majors is a 3 credit hour introductory engineering course that is required for all first semester engineering students and open to all students at the university. Half of the student outcomes in the course are focused on the engineering profession: explain the basic practice of engineering, describe background histories, impact on society, skills employed, and professional/ethical responsibilities; summarize the knowledge bases, skills, problem types, and analysis techniques of the four engineering disciplines offered at Quinnipiac University; and analyze information provided and learned to make an informed decision about choice of an engineering major. These outcomes are focused on raising student knowledge of engineering disciplines in order to enhance their ability to make an informed decision about choice of an engineering major.

An important part of the course designed to solidify the class discussions is the hands-on activity that follows each of the modules associated with the four majors. This has been proven to be an effective technique in improving student learning.[8] Research has also shown that discipline-specific activities are more effective in motivating students to develop their own understanding[9]; as a result, the introductory course was designed with hands-on activities related to the particular engineering major, rather than engineering in general. The civil engineering module requires student teams to build a pasta tower to a specific height, using a specified bill of materials, to hold various volumes of water. The tower then has to withstand vibrations on an earthquake table. The industrial engineering activity involves the seat design of a commercial airline, as well as optimizing the routing of the airplane to maximize revenue generation. For the Mechanical Engineering module, student teams design and build a water-powered rocket, using a 2L soda bottle. Lastly, for the software engineering module, student teams designed, developed, documented and presented an Android app, using MIT App Inventor.

At the start of the course students are surveyed to collect data on the major in which they are currently registered, initial actual knowledge of engineering disciplines, initial perceived knowledge of engineering disciplines, initial interest in a specific engineering major, and reasons for selecting engineering (or taking course for non-engineering majors.) The same survey was distributed to the students at the end of the course. The pre- and post-course surveys are provided in Appendix 1. The results of surveys are used to analyze the following four questions. We recognize that students' knowledge and interest are affected by their greater environment, most notably interaction with other students. However, we assume the knowledge gained through the course to have a greater effect on the students' evolution of knowledge and interest, evaluated through the pre- and post-course surveys.

This paper investigates four topics:

1. Is there a correlation between a student's initial desire to pursue a specific engineering major and their actual and perceived knowledge of that engineering discipline?
2. For those students who are interested in and knowledgeable about a specific engineering discipline, does the introductory course strengthen that interest?

3. For those students who are unsure about what specific engineering discipline to choose, are the students more likely to be interested in a specific engineering discipline at the end of the course?
4. Does the introductory course increase students' knowledge, actual and perceived, about the specific engineering disciplines?

There were 72 students enrolled in the course in the fall of 2013. At the beginning of the semester, 13 of these students had declared a major other than engineering (not engineering), and 10 were undeclared engineering majors. The remainder had declared one of the four engineering majors offered at Quinnipiac University: 11 Civil Engineering (CE) majors, 1 Industrial Engineering (IE) major, 23 Mechanical Engineering (ME) majors, and 14 Software Engineering (SE) majors. As will be discussed later in the paper, it is difficult to make quantitative judgments about all four of the above topics due to the small sample size for most of the majors. However, some qualitative observations can be made about the data.

Question 1: Is there a correlation between a student's initial desire to pursue a specific engineering major and their actual and perceived knowledge of that engineering discipline?

The information to answer this question was taken from the initial survey. The students were asked to define each of the disciplines and then indicate how confident they were in their definitions on a Likert scale where 1 was very unsure and 5 was very confident. Discipline-specific faculty members then rated the students' definitions, also on a Likert scale. The students were also asked their level of interest in each of the four disciplines offered by the university:

I am considering pursuing the following disciplines: (Circle the appropriate number):
1- Strongly disagree 2- Disagree 3- Neutral 4- Agree 5- Strongly Agree

a) Civil Engineering	1	2	3	4	5
b) Industrial Engineering	1	2	3	4	5
c) Mechanical Engineering	1	2	3	4	5
d) Software Engineering	1	2	3	4	5

Figure 1 – Survey question to determine level of interest

The students' interest and their perceived knowledge (how confident they were in their definition) in each discipline were plotted and compared with a plot of the students' interest and actual knowledge (the rating of the students discipline definition by the faculty). As shown in Figures 2-5, there appears to be no correlation between the students' interest in a particular discipline, and their knowledge of that discipline. In the figures, each dot represents a single student's response. It is important to track the number of responses; therefore, points that would otherwise be overlaid are displayed closely alongside each other.

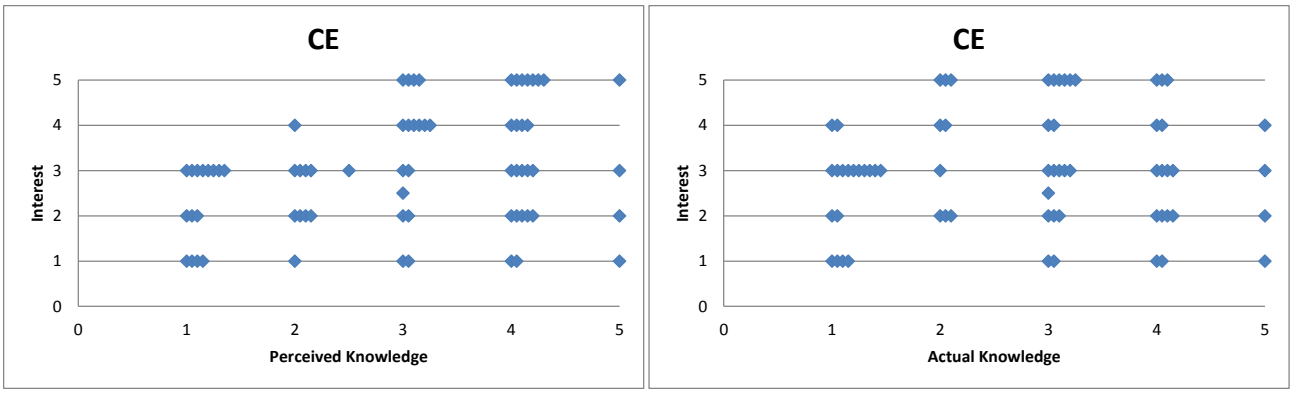

Figure 2. CE Interest vs Actual and Perceived Knowledge

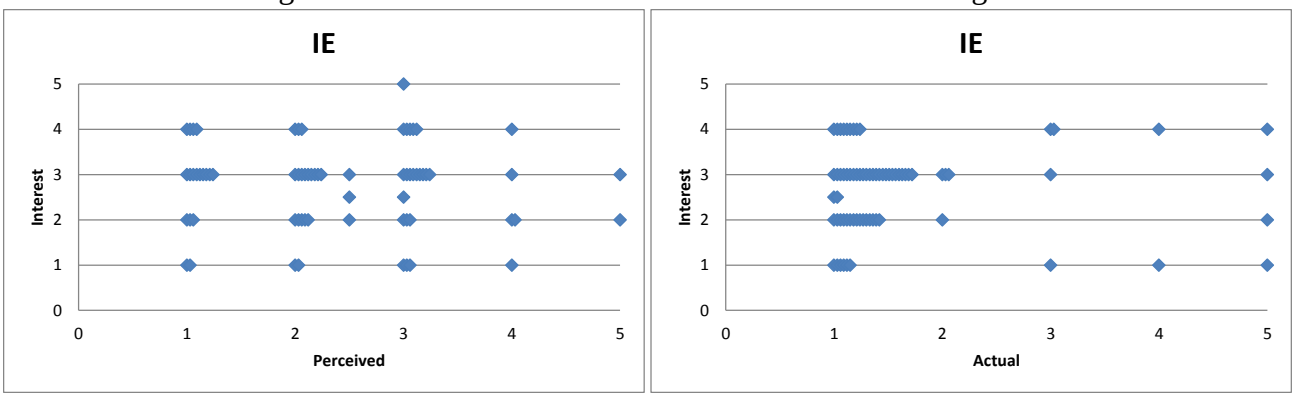

Figure 3. IE Interest vs Actual and Perceived Knowledge

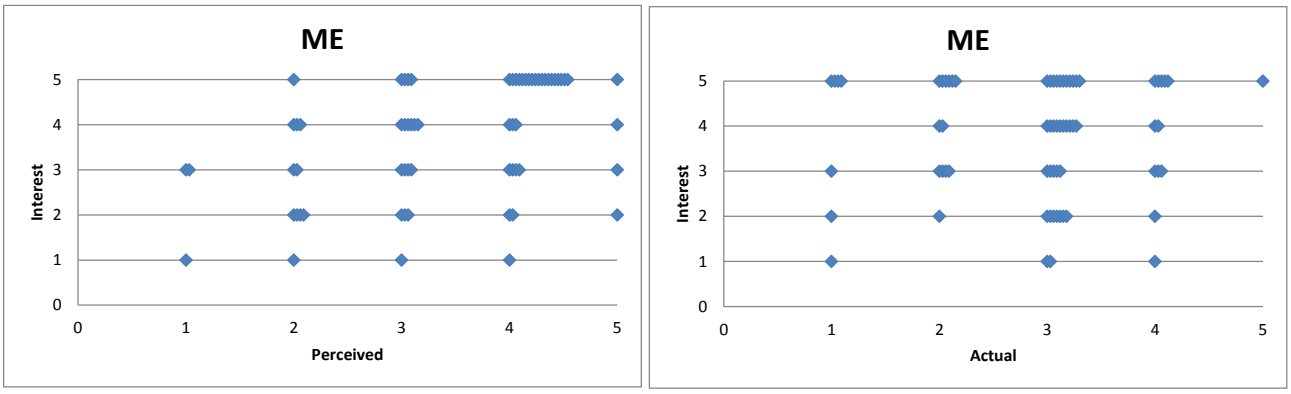

Figure 4. ME Interest vs Actual and Perceived Knowledge

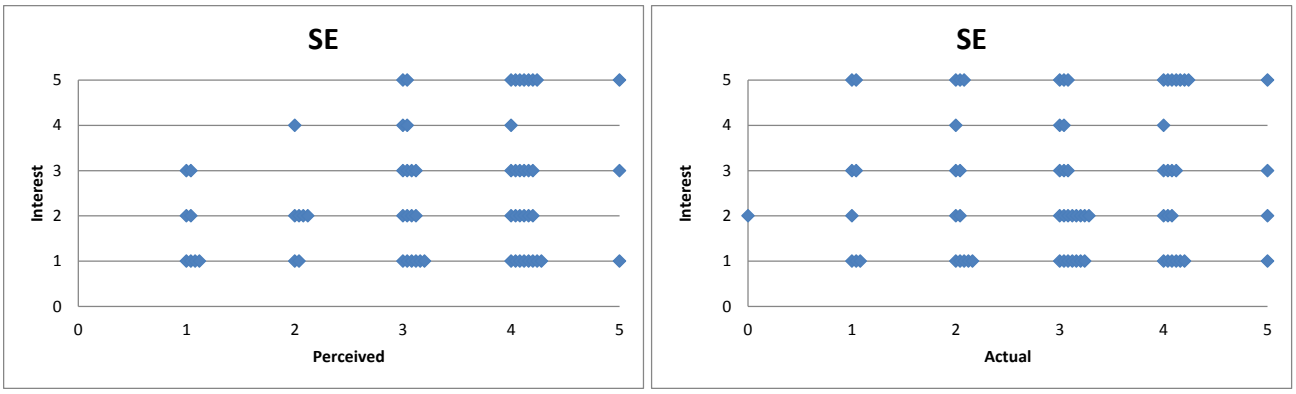

Figure 5. SE Interest vs Actual and Perceived Knowledge

Additionally, correlation coefficients were calculated and test of hypotheses were conducted to test for the absence of correlation. The correlation coefficients (Table 1) support the evidence from the graphs that there is little to no correlation between a student's interest in a major and their actual or perceived knowledge of that discipline. For the test of hypotheses, the standard null and alternative hypotheses of $\rho = 0$ and $\rho \neq 0$, respectively, were used. The results, p-values, of these test with sample size of n=72 (Table 1) show that statistically there is an absence of correlation in five of the relationships supporting the claim of no correlation. Only those for perceived knowledge for civil, mechanical, and software are statistically significantly different from zero. However the values of these Correlation Coefficients (0.29, 0.44, 0.39) are too low to indicate that perceived knowledge is the primary factor in a student's interest in an engineering discipline.

Table 1. Correlation Coefficients

	Perceived knowledge (p-value)	*Actual knowledge (p-value)*
CE	**0.29 (< 0.05)**	0.02 (0.85)
IE	-0.11 (0.37)	0.09 (0.46)
ME	**0.44 (< 0.01)**	0.02 (0.90)
SE	**0.40 (< 0.01)**	0.13 (0.29)

The lack of a correlation may be due to the small sample size, and these questions will continue to be asked on the introduction to engineering course surveys as part of the planned longitudinal study.

Question 2: For those students who are interested in and knowledgeable about a specific engineering discipline, does the introductory course strengthen that interest?

In this case, interest was determined by a student declaring a specific engineering major. They were determined to be knowledgeable about that particular discipline by scoring 3 or higher in

the actual knowledge rating done by the faculty. In order to determine whether or not a student's interest in their declared major was strengthened, the sum of the difference in the interest scores (from question shown in Figure 1) between the initial and final surveys was calculated as shown in the equation below. A positive interest score indicates that the interest was strengthened by an increase in the interest in the declared major and/or a decrease in the interest in the other three majors.

$$Interest\ Score = (Final\ Interest - Initial\ Interest)_{declared\ major} + \sum_{i=1}^{3} (Initial\ Interest - Final\ Interest)_{other\ majors}$$

Civil Engineering

Of the 11 civil engineering majors at the start of the course, seven were determined to be knowledgeable about the major. By the end of the course, five of the seven demonstrated a strengthened interest in civil engineering with a positive interest score. The score for one of the other two students was zero, indicating that that student's interest did not change. The student reported an interest of 5 in civil engineering and 1's for the other three disciplines on both initial and final surveys. The remaining student scored a -1, and although that student reported a 5 in civil engineering in both surveys, she reported an increase in interest from 3 to 4 in one of the other disciplines.

Industrial Engineering

There was only one industrial engineering major was interested and knowledgeable in the discipline. Her interest score was 5, and her interest in IE remained at a 5 throughout the semester, and her interest in the other three disciplines transformed from {3,3,2} to {1,1,1}. Given the sample size of one for IE, no meaningful statements can be made.

Mechanical Engineering

11 students were determined to be interested in and knowledgeable about mechanical engineering. At the end of the course, six of the 11 demonstrated a strengthened interest in mechanical engineering with a positive score. Again, one student scored a zero, with 5s for ME and 1s for the other disciplines on both surveys. The remaining four students' interest scores were negative. For three of these four students, their interest in ME stayed constant at 5 for both surveys, and the negative score indicates a strengthened interest in one or more of the other disciplines. Only one student showed a decrease in interest in ME, scoring a 5 in the initial survey and a 4 in the final survey.

Software Engineering

Six students were determined to be interested and knowledgeable about software engineering. At the end of the semester, two of these students demonstrated a strengthened interest in their major with a positive interest score. Three scored a zero, with their interest in software engineering remaining at a 5 through the course of the semester. The remaining student's

interest in software engineering went from a 5 to a 4, and his interest in civil engineering went from a 2 to a 4. As of this writing, however, he is still a software engineering major.

Question 3: For those students who are unsure about what specific engineering discipline to choose, are the students more likely to be interested in a specific engineering discipline at the end of the course?

At the start of the semester, there were 23 students in the course who had not declared a major in one of the four engineering majors offered at Quinnipiac University, and were either undeclared engineering (10 of 23) or had a declared major in a subject other than engineering (13 of 23). Eight of the students who had a declared major in a subject other than engineering had no intention of ever majoring in engineering, and took the introduction to engineering course because 'it looked interesting' or 'plan to work with engineers.' Four of the students who started the semester as undeclared engineering majors did not complete the final survey. Therefore these 12 students were removed from the analysis of Question 3 leaving an overall sample size of 11 students, five non-engineering majors and six undeclared engineering. Given the extremely small sample size only qualitative analysis was performed.

Of the five remaining students who started the semester in a major other than engineering, four switched to either undeclared engineering or to a specific engineering discipline, and the fifth is wavering between science and a specific engineering discipline. For the six students who started the semester as undeclared engineering majors, three changed their major from undeclared to a specific discipline, two are leaning toward a specific discipline, and one is still deciding. At the end of the semester seven of 11 students that were unsure at the start have selected an engineering major, three are deciding between only two different majors and only one remains unclear. Therefore, for this semester, the authors claim that for students that were unsure of a specific engineering discipline by the end of the course they are more likely to be interested in a specific engineering discipline as 10 out of 11 students have clearly focused their interest.

Question 4: Does the introductory course increase students' knowledge, actual and perceived, about the specific engineering disciplines?

The introductory course increases the students' knowledge, both their perceived knowledge, as well as their actual knowledge, about the specific disciplines as show in Figures 6-9. In these figures, the students' actual knowledge is plotted versus their perceived knowledge from both the initial survey and the final survey.

By the end of the term, after the students go through the introductory engineering course, the strong majority have a reasonably good knowledge about the four engineering disciplines. This is evident in the majority of the data points falling in the upper right quadrant of Figures 6-9 (Final) (again, each dot represents a single student's response).

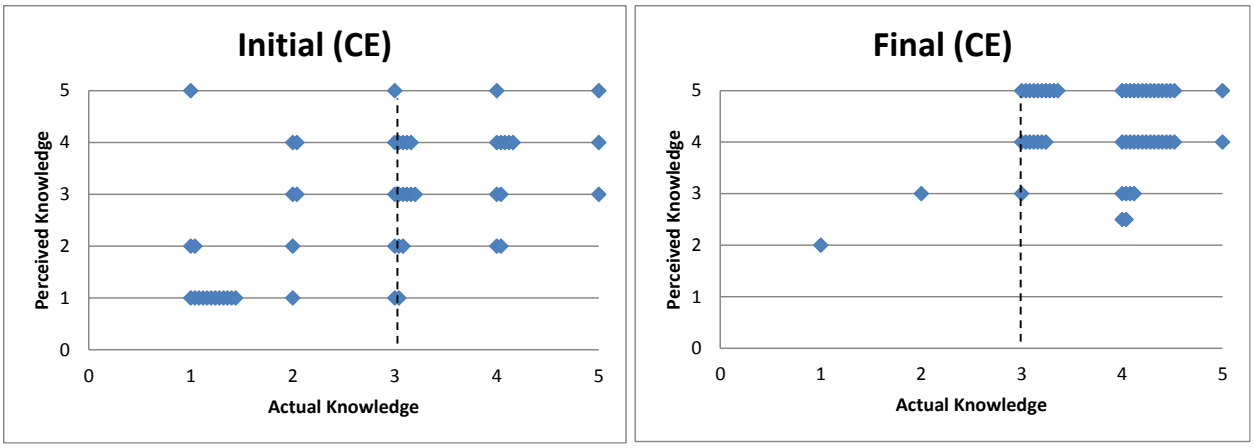

Figure 6. CE Actual vs Perceived Knowledge – Initial and Final

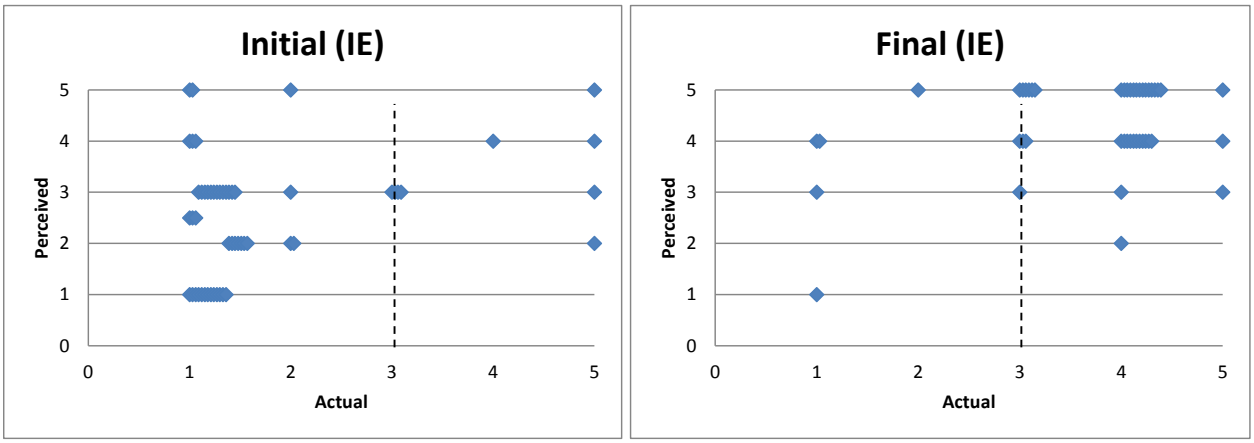

Figure 7. IE Actual vs Perceived Knowledge – Initial and Final

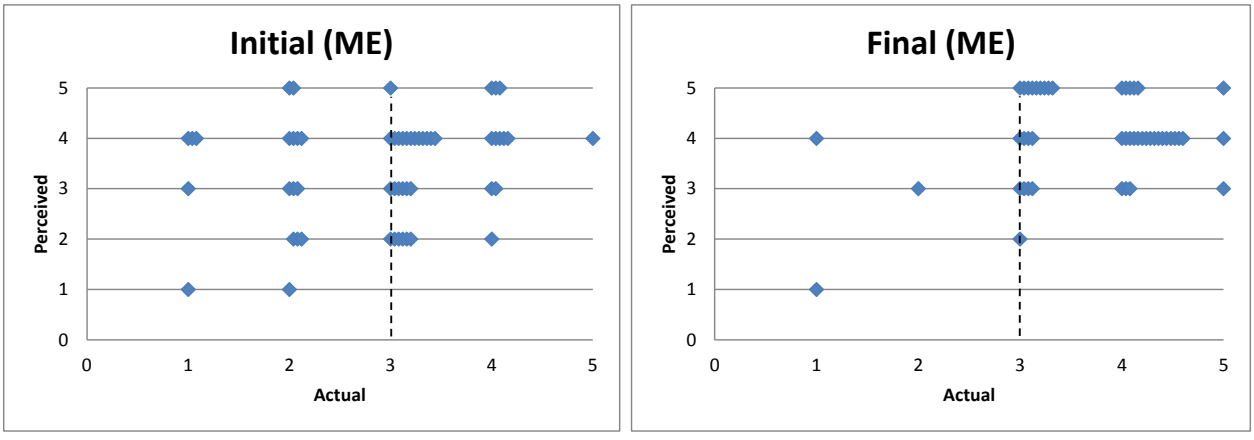

Figure 8. ME Actual vs Perceived Knowledge – Initial and Final

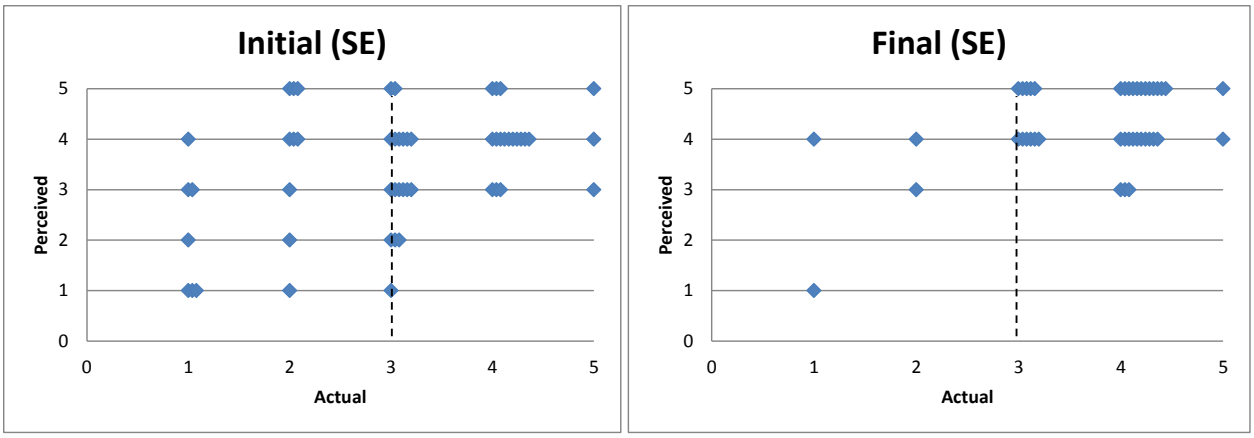

Figure 9. SE Actual vs Perceived Knowledge – Initial and Final

Additionally, paired t-test were performed to test for an increase in knowledge from the initial to final surveys. The average values and difference between the surveys (Table 2) support the evidence from the graphs that students increase both their actual and perceived knowledge of the disciplines. For the test of hypotheses the standard null and alternative hypotheses of $\mu_\Delta = 0$ and $\mu_\Delta \neq 0$, respectively, were used. The results of these test, p-values, for sample size n = 72 (Table 2) show that statistically these increases in knowledge are significant.

Table 2. Averages and Differences

		Initial	*Final*	*Increase (p-value)*
CE	*Perceived knowledge*	*2.83*	*4.17*	*1.33 (<0.01)*
	Actual knowledge	*2.89*	*3.71*	*0.82 (<0.01)*
IE	*Perceived knowledge*	*2.55*	*4.33*	*1.78 (<0.01)*
	Actual knowledge	*1.56*	*3.81*	*2.25 (<0.01)*
ME	*Perceived knowledge*	*3.50*	*4.12*	*0.62 (<0.01)*
	Actual knowledge	*2.82*	*3.45*	*0.64 (<0.01)*
SE	*Perceived knowledge*	*3.43*	*4.30*	*0.87 (<0.01)*
	Actual knowledge	*3.11*	*4.25*	*1.14 (<0.01)*

Conclusion

In this paper, we have investigated the effects of an introductory engineering course on student knowledge and their selection of a major. This paper serves as the first step in a longitudinal

study that will compile data from multiple students across multiple years to investigate the whether initial knowledge and interest have a relationship with retention and satisfaction rates.

Many students enter the program with little knowledge on some of the engineering disciplines offered at Quinnipiac University. Some are cognizant of their unawareness. Throughout the semester, the students go through several lessons on each of the four disciplines as well as a hands-on project. By the end of the course, the strong majority of the students are aware of the nature of each of the four engineering careers.

Due to the small size in the current data set, we are not able to draw any other statistically significant conclusions. However, our analysis does provide support for some of our hypothesis. One such example is the course further strengthening the students' interest in the major of their choice. Evidence points to the fact that the course is helping students narrow their choice down to one major by the end of the term. However, this can only be stated as a qualitative statement and not a statistical conclusion. Nevertheless, such findings are encouraging and pave the way for further analysis in the near future upon collection of new data.

Our future work will be to continue to collect data on incoming freshman students, their initial interests, knowledge levels, and their progress and transformations throughout the first term. In addition, we plan to follow the students throughout the four years of engineering studies, quantitatively monitoring their performance, as well as qualitatively gauging their satisfaction with the chosen major. Once complete, the collection of this work can contribute to the literature and provide support for universities considering similar introductory engineering courses. As another future endeavor, it will be quite interesting to compare our results to the results of another institution. Given the fact that we are a mainly-teaching university, we can compare our results to that of s similar course but from a dissimilar institution, such as an R1 institution.

References

1. Tinto, V., *Leaving College: Rethinking the Causes and Cures of Student Attrition*, Chicago, IL: The University of Chicago Press, 1987.
2. Marra, R. M., Rodgers, K. A., Shen, D. & Bogue, B., "Women engineering students and self-efficacy: A multi-year, multi-institutional study of women engineering student self-efficacy," *Journal of Engineering Education, 98*(1), 27–38, 2009.
3. Marra, R. M., Shen, D., Rodgers, K. A., & Bogue, B., *Those that leave - Assessing why students leave engineering.* Paper presented at the American Society for Engineering Education, Honolulu, HI., 2007.
4. Johnson, M.J., and S.D. Sheppard. "Students Entering and Exiting the Engineering Pipeline-Identifying Key Decision Points and Trends." In *2002 Proceedings of 32nd ASEE/IEEE Frontiers in Education Conference, Session S3C.*
5. Seymour, E., and N. Hewitt. *Talking about Leaving: Why Undergraduates leave the Sciences*, Boulder: Westview Press, 1997.

6. Marra, R. et al, “Leaving Engineering: A Multi-Year Single Institution Study,” *Journal of Engineering Education*, Vol. 101, No. 1, January 2012.
7. Knight, D.W., et al., “Improving Engineering Student Retention through Hands-On, Team Based, First-Year Design Projects,” in *2007 Proceedings of the 31st International Conference on Research in Engineering Education*.
8. Boettner, D., Byers, L, et al., “Teaching Design in Context,” Presented at the 2008 ASME International Mechanical Engineering Congress and Exposition, Boston, MA, November 2-6 2008.
9. Reap, J., Matusovich, M., Louis, R.A., “Chocolate Challenge: The Motivational Effects of Optional Projects in an Introductory Engineering Class”, *ASEE Annual Conference and Exposition*, June 10-13, 2012. San Antonio, Texas.

Appendix 1: Surveys

1A: The following survey is conducted at the start of the term to assess initial knowledge and interest:

Student Initial Knowledge

Please circle the major in which you are currently registered:

Mechanical Industrial Civil Software Undeclared engineering Non-engineering

I am considering pursuing the following disciplines: (Circle the appropriate number):

2- Strongly disagree 2- Disagree 3- Neutral 4- Agree 5- Strongly Agree

a) Civil Engineering	1	2	3	4	5
b) Industrial Engineering	1	2	3	4	5
c) Mechanical Engineering	1	2	3	4	5
d) Software Engineering	1	2	3	4	5
e) Other_____	1	2	3	4	5

Answer the next four questions and indicate how confident you are with your response for each:

1- Very Unsure 2- Somewhat unsure 3- Neutral 4- Somewhat confident 5- Very confident

What does a Mechanical Engineer do?	1	2	3	4	5

_____

What does a Civil Engineer do?	1	2	3	4	5

_____

What does a Software Engineer do?	1	2	3	4	5

_____

What does an Industrial Engineer do?	1	2	3	4	5

_____

If you are currently in Engineering, list three reasons why you chose Engineering as the degree to pursue.

_____

_____

If you are NOT currently in Engineering, list three reasons why you are taking this course.

_____

_____

If you did not initially start out in Engineering, list your top reasons why you switched to Engineering.

_____

_____

1B: The following survey is conducted at the end of the term to assess gained knowledge and interest:

Student Final Knowledge

Please circle the major in which you are currently registered:

Mechanical Industrial Civil Software Undeclared engineering Non-engineering

I am considering pursuing the following disciplines: (Circle the appropriate number):

3- Strongly disagree 2- Disagree 3- Neutral 4- Agree 5- Strongly Agree

a) Civil Engineering	1	2	3	4	5
b) Industrial Engineering	1	2	3	4	5
c) Mechanical Engineering	1	2	3	4	5
d) Software Engineering	1	2	3	4	5
e) Other_____	1	2	3	4	5

Answer the next four questions and indicate how confident you are with your response for each:

2- Very Unsure 2- Somewhat unsure 3- Neutral 4- Somewhat confident 5- Very confident

What does a Mechanical Engineer do? 1 2 3 4 5

_____

What does a Civil Engineer do? 1 2 3 4 5

_____

What does a Software Engineer do? 1 2 3 4 5

_____

What does an Industrial Engineer do? 1 2 3 4 5

_____

If you are planning on pursuing an Engineering degree, what is your primary reason(s)?

_____

_____

If you are NOT planning on pursuing an engineering degree, what is your primary reason(s)?

_____

_____

This course played a role in my decision

1- Strongly disagree 2- Disagree 3- Neutral 4- Agree 5- Strongly Agree