



## Identifying Factors for Retention of Engineering Students in the First Two Years

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# Identifying Factors for Retention of Engineering Students in First 2 Years

## Abstract

The first two years are the most critical years for retaining engineering students. To determine the factors impacting engineering student retention, an electronic survey was implemented to assess the motivation for choosing engineering and individual feedback on engineering program. This survey builds upon institutional data and a previous survey sent to non-retained students. The survey was given in the course *Engineering Mechanics: Statics* to capture majority of 3rd or 4th semester Civil Engineering, Environmental Engineering, Mechanical Engineering, and Biomedical Engineering students at Colorado State University. This paper will summarize the results of the survey and discuss related program improvements which could bolster retention rates.

## Introduction

Retention of undergraduate engineering students has been identified to be lower than retention in non-engineering undergraduate curriculum [1, 2]. The American Society of Engineering Education (ASEE) and the Presidents Council on Jobs and Competitiveness proposed that low retention is a result of a learning environment that fails to motivate and engage engineering students [2, 3]. Based on data from a 2007 study, the higher the retention from year one to year two, the higher the overall graduation rate. Student-focused cultures cultivated in the first two years were shown improve degree completion and graduation within a variety of engineering colleges [4]. Various factors that affect student retention have been identified including: (1) academic related factors; (2) poor teaching and advising; (3) difficulty of the engineering curriculum; and (4) students' belief that they do not belong in engineering [1, 2, 5].

A study at University of Colorado (CU) Boulder [6] concluded that a hands-on approach to engineering education greatly benefited overall retention, particularly in underrepresented populations. The researchers implemented a course called First-Year Engineering Projects, which required hands-on design experience which emphasized teamwork and successful implementation of a student-researched plan [6]. Traditionally, such an experience would not occur for engineering students until the final year of their program, in the form of a Senior Design or Capstone project.

Alternatively, low retention rates in engineering curriculum have been attributed to difficulties insufficient support in non-engineering core math and science courses required to be taken by engineering students in their first year [7]. At Colorado State University, a program implementing additional engineering support for basic science courses was assessed for effects

on retention. The study found that support in math and science courses was a smaller issue than initially perceived; concluding that few students took advantage of the additional support, and retention rates did not change significantly as a result of this program [8]. The scope of this initial study was very limited due to the voluntary participation of undergraduates in the basic science support curriculum. Thus, a more comprehensive survey of retention of 1<sup>st</sup> and 2<sup>nd</sup> year students is needed to lead to a more informed understanding of factors reducing retention.

The potential sources of retention problems were investigated by surveying students registered at the College of Engineering at CSU in the Engineering Mechanics course. To get a comprehensive understanding of the program the following information was collected from students: (1) initial impetus for students to enroll in engineering; (2) evaluate different parameters in the program; (3) evaluate the importance of different parameters in the Engineering study; and (4) demographic information.

## Methodology

The survey in this study is a continuation of a study given to students that had left the Walter Scott, Jr. College of Engineering at CSU since 2012. The previous study was sent to 760 students who left the college of engineering before completing their undergraduate degree (“non-retained”), of whom 185 students responded (24.3 % response rate) (unpublished data Huq, 2017). The current study was conducted in *Engineering Mechanics: Statics* (“Statics”) in the Fall semester of 2017. Statics is a required course for Civil Engineering, Environmental Engineering, Mechanical engineering, and Biomedical Engineering students, and is an optional elective for Chemical and Biological Engineering students. Most students take Statics in the third semester of their engineering coursework. A survey was sent to 275 students (online and in-class students) and a total 207 students responded to survey (75 % response rate).

This survey contains 4 sections (below). Note that all data is self-reported.

- General information: student’s home department, the first semester registered at CSU, the number of credits passed prior to this semester, current GPA range, and their intentions for the following semester for whether or not they planned to remain in the College of Engineering
- Demographic data: including gender, race, and educational identification (e.g. non-traditional student).
- Background: Top 3 reasons that they initially choose engineering.
- Program satisfaction: Using a Likert scale between 1 and 5 (1 = fully satisfied and 5 = fully dissatisfied). Additionally, students were asked to evaluate the importance of each parameters for their study by grading from 1 to 5 (1 = least important parameter, 5 = most important factor).

The first and second sections of the survey were reported in this section (Methodology) and third and fourth sections of survey was analyzed in the Result and Discussion section.

The home departments of students who participated in the study are listed in **Table 1**. More than two thirds of students who participated in the study were civil engineering and mechanical engineering students. More than 41 % of students earned 31-45 credits, 25 % earned 16-30 credits, 12 % earned 45-60 credits, 11 % earned 45-60, and 11 % earned more than 61 credits prior to the semester of study. More than two third of students who participated in the study were in their third semester at CSU. One quarter of students had a GPA ranging between 3.51-4.0, 39 % had a GPA ranging between 3.01 to 3.5, 28 % of students had a GPA ranging between 2.51 to 3.0, and 7 % of students had GPA between 2 to 2.5.

**Table 1.** Home department of participants.

Home Department	Number of Students	Percent (%)
Civil Engineering	91	44.0
Mechanical Engineering	59	28.5
Environmental Engineering	21	10.1
Biomedical Engineering	15	7.2
Chemical and Biological Engineering	9	4.3
Other	12	5.8
Sum	207	100

From all students who participated in the study, 93 % plan to stay at College of Engineering at CSU, 4 % of students have considered/are considering leaving the College of Engineering, and 2 % of students have already decided to leave the College of Engineering. 72 % of participants in the study were male students and 28 % were female students. 81 % of students were white, 9 % of students were Hispanic or Latino, and 8 % were Asian students.

The reliability of survey was evaluated by repeating two questions in survey. A Spearman correlation test was conducted on these two questions resulted in P-values < 0.05 which suggested a correlation between results from repeated questions.

## Results and Discussion

Reported results in this study are self-reported and did not validate with university data base. Results are organized in two major sections: (1) all students: discuss and analyze the results obtained from all students; and (2) potentially non-retaining students: analyze the responses from students who stated that “I have considered/am considering leaving the College of Engineering” and “I plan to leave the College of Engineering, but stay at CSU” (total of 6% of respondents).

### All students

Students were asked to choose the top-three reasons that they initially selected engineering as their undergraduate major. A summary of student responses is shown in **Table 2**. The total number of responses in **Table 2** are more than 207 which is due to the ability of students to choose 3 options. More than three quarters of student responses read that they believed that they are “good at math and science”. More than half of students chose engineering because they “wanted to make a positive impact on society through engineering”. Reasons based on recommendations from other people including: “a guidance counselor told me to go into engineering”, “family pressure”, “family encouragement”, or reasons based on students’ previous experiences: “I participated in engineering related coursework in high school” was selected in the lowest rate. Results in **Table 2** suggests that students primary reason for having selected engineering was due to their personal intellectual capacity and the positive societal implications of engineering as a discipline; however, it appears that outside recommendation did not play an important factor in students selecting engineering.

**Table 2.** A summary of reasons that students initially chose engineering. Students were asked to select top three reasons.

<b>Why did you initially choose engineering?</b>	<b>Number of Students</b>	<b>Percent (%)</b>
I am good at math and science	158	76.3
I wanted to make a positive impact on society through engineering	108	52.2
High salary	98	47.3
It sounded enjoyable	92	44.4
Hands-on aspect	92	44.4
Heard it was a marketable major/would give me job security	87	42.0
A family member/friend is an engineer	61	29.5
Family Encouragement	54	26.1
I participated in engineering related coursework in high school	54	26.1
Family pressure	16	7.7
A guidance counselor told me to go into engineering	11	5.3

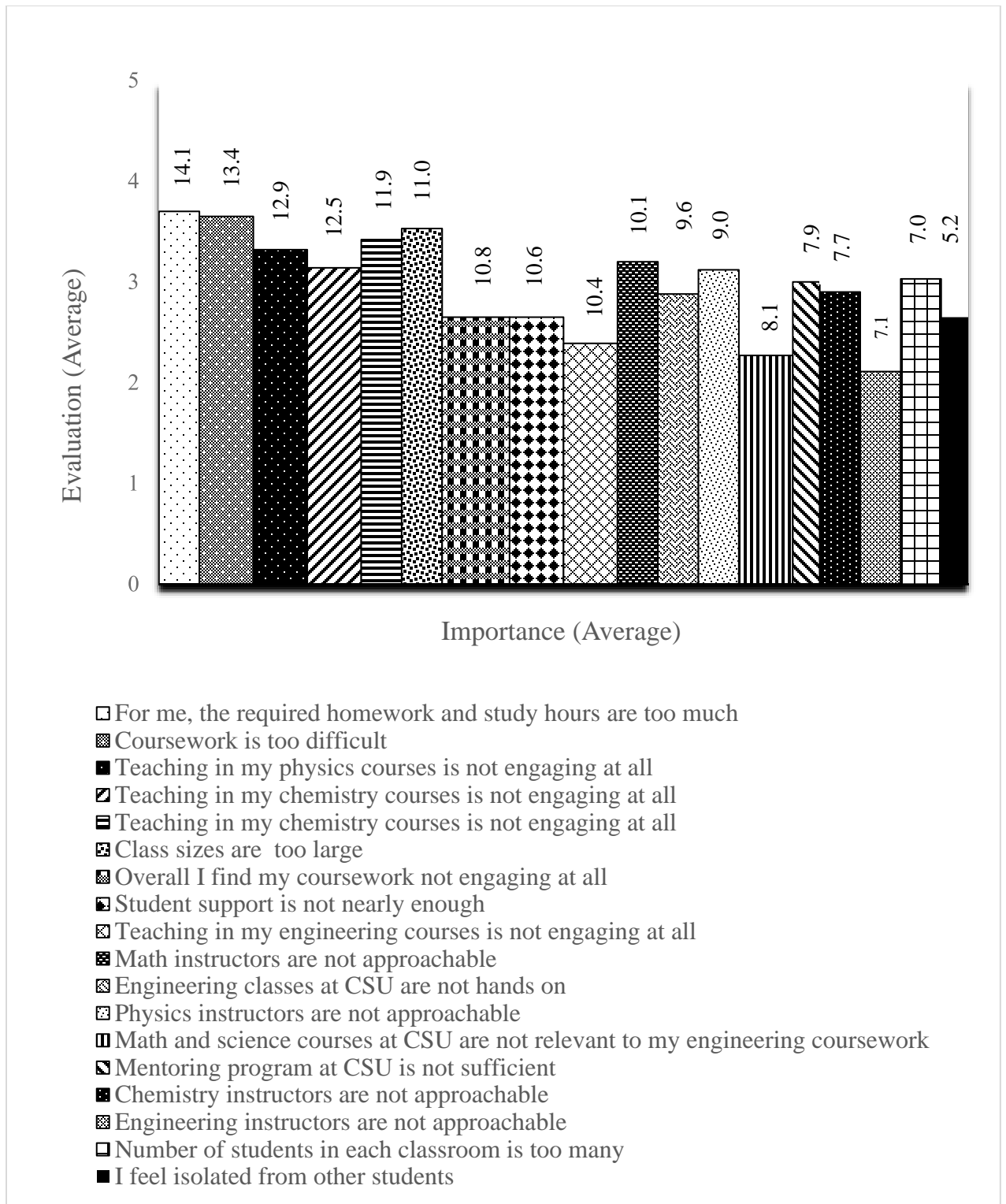
**Table A-1 in Appendix A** contains a summary of the responses from survey Section 4, asking students to evaluate their level of satisfaction with their program (where 1 is fully satisfied and 5 is fully dissatisfied). This summary includes the average response values, average importance of each factor where 1 is not important, and 5 is extremely important, and two parameters what are referred to as multiplication parameter and division parameter. The multiplication parameter is a value calculated by multiplying “average evaluation score” by “importance”. A higher multiplication parameter suggests that students are not only dissatisfied about a factor, but also that factor is important for them. A higher multiplication factor is representative of weakness in the CSU engineering program; however, a factor with a lower

multiplication parameter does not represent strength in the program. This is because a factor with low multiplication parameter suggesting that students are either satisfied with that factor OR the factor is not important for them. For evaluating the strengths of the engineering programs at CSU division parameter was used. The division parameter is a value calculated by dividing “average evaluation score” by “importance”. A lower division parameter suggests that students are both satisfied with a parameter (low dissatisfaction score) and also that factor is important to them.

Summary of evaluation results for determining the weaknesses of the program are shown in **Figure 1**. The Y-axis is the average evaluation score of students, where 5 suggesting students are totally dissatisfied and 1 suggesting students are totally satisfied. The width of each bar on the X-axis is the average importance of each factor in **Figure 1**. The area under each bar is equivalent to the multiplication factor. Factors in **Figure 1**, are organized based on the multiplication factors in the way that factors with the highest multiplication parameter are in the left side of plot. Parameters that had the highest multiplication parameter are “the required homework and study hours are too much,” “coursework is too difficult,” and “teaching in my physics courses is not engaging”. These results suggest that students believe the coursework load is high for students.

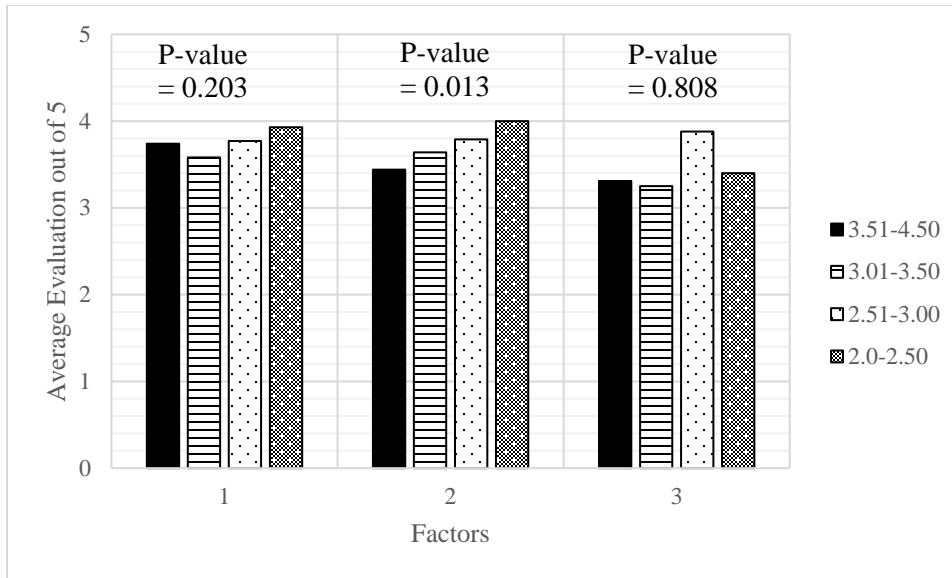
The relationship between the average satisfaction of students and their GPA range for these three factors was further investigated and results are shown in **Figure 2**. The only factor that showed a correlation between students’ GPA and average evaluation score was “coursework is too difficult,” in that students who had a lower GPA found coursework more difficult. This result suggests that students with lower GPA needs more support in their coursework.

In order to highlight aspects of engineering education that the sample of students valued most, factors from the survey ranked by students as most important to their education are highlighted in **Table 3**. The parameters are “engagement of students in teaching in engineering courses,” “engagement of overall coursework,” and “student support.” Average Students’ satisfaction for these three factors had an average ranking between 2.39 to 2.65 out of 5 suggesting that students are satisfied in the most important parameters.



**Figure 1.** Average dissatisfaction, importance, and multiplication parameter of questioned factors for students' education focusing on the weaknesses in College of Engineering at CSU. Numbers listed on the top of bars are multiplication parameter. Factors are sorted based on multiplication parameters.





**Figure 2.** Relationship between the GPA of students and average evaluation for the factors with the factors that had the highest multiplication factor (Average  $\times$  Importance). Factor 1: the required homework and study hours are too much, factor 2: coursework is too difficult, and factor 3: teaching in my physics courses is not engaging. P-values obtained based on Mann-Whitney test.

**Table 3.** The most important factors in student’s engineering education.

The most important factors	Average Importance	STD	Average Satisfaction Evaluation
Engagement in teaching in engineering courses	4.33	0.85	2.39
Engagement in Overall coursework	4.09	0.95	2.65
Student support	4.01	1.01	2.65

In order to bring attention to shortcomings of the program based on this dataset, **Table 4** summarizes the aspects which students, on average, seemed least satisfied with. Students selected “the required homework and study hours are too much”, “coursework is too difficult”, and “class sizes are too large” as the least satisfying factors. All of these aspects had relatively high importance for the participants on average, with importance ranging between 3.11 to 3.82.

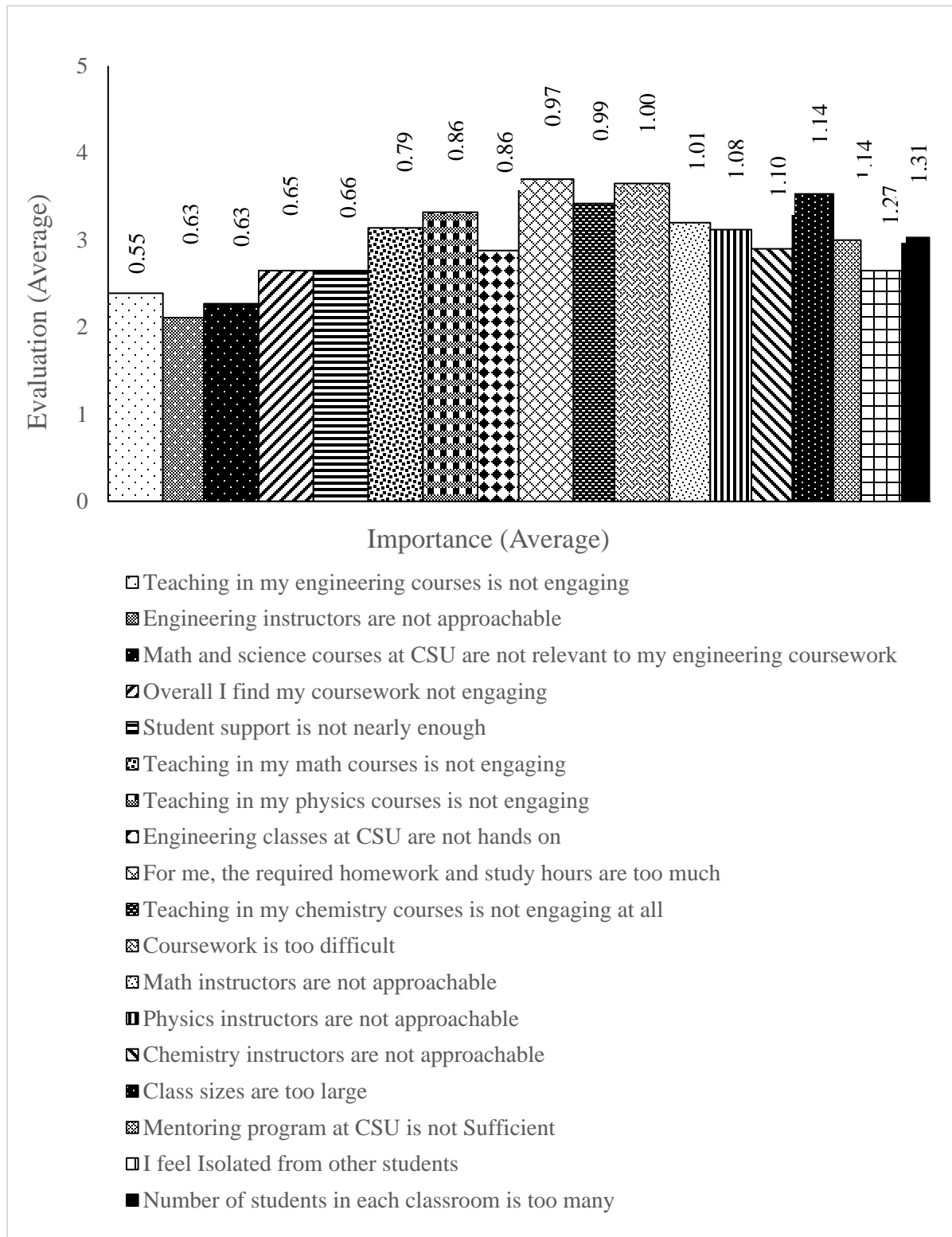
**Table 4.** The least satisfying factors in student’s engineering education.

Least satisfied Factors	Average Satisfaction Evaluation	STD	Average Importance
For me, the required homework and study hours are too much	3.70	0.67	3.82
Coursework is difficult	3.65	0.58	3.66
Class sizes are large	3.53	0.67	3.11

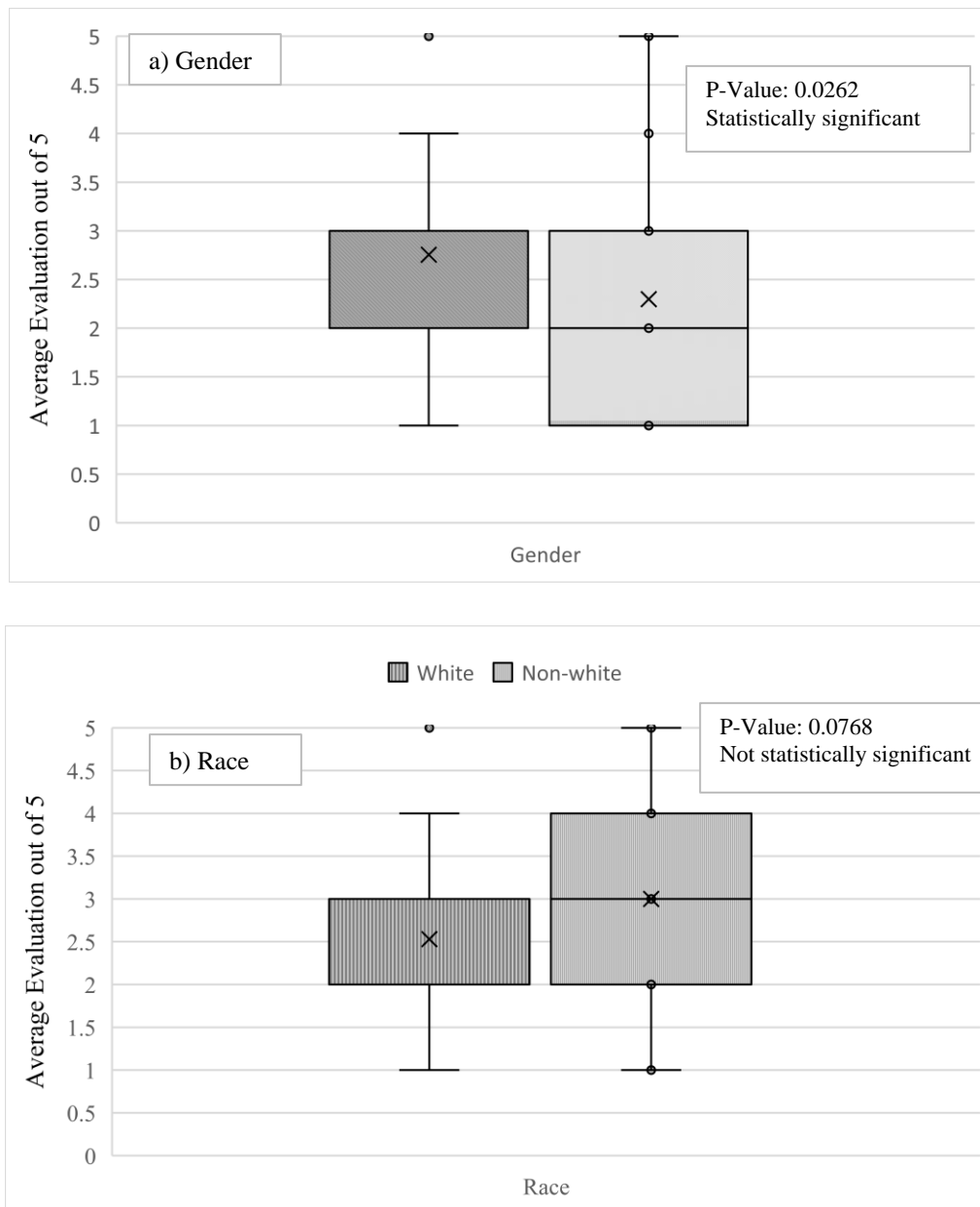
The response of students to engagement in science classes and engineering classes were compared (an evaluation of suggests total satisfaction and an evaluation of 5 suggests total dissatisfaction). The average evaluation of students in engagement in chemistry, physics, and math classes were 3.42, 3.32, and 3.14, respectively. The students' satisfaction in engagement in engineering classes was 2.39 suggesting that students found engineering classes more engaging than science classes. A t-test performed to evaluate the statistical significance of responses from engagement in science classes (math, physics, and chemistry classes) and engagement in engineering classes. The P-value was less than 0.0001 suggesting that students' satisfaction is statistically higher in engagement in engineering classes in comparison with engagement in science classes.

Division factor was used to evaluate the strength of the program which suggests that a factor not only had a low dissatisfaction factor (low evaluation value), but also has a high importance for students. The average evaluation and importance of factors are listed in **Figure 3**. In **Figure 3**, the Y-axis contain the average evaluation of a factor and the X-axis contain the importance. Factors in **Figure 3** are organized to have the lowest division factor on the left. The highest strengths in the CSU's program are "teaching in my engineering courses is engaging" and "engineering instructors are approachable". These factors suggest that the content and teachers in engineering classes are satisfying for students.

A question was asked from students targeting their social situation in the College of Engineering, reading "I feel involved with/isolated from other students", where score of 1 suggests students feel involved with other students and score of 5 means students feel isolated from other students. The response of students based on their gender and race was evaluated and results are shown in **Figure 4**. The investigated hypothesis in this section was that the minorities (gender and race minorities) in the College of Engineering feel more isolated from other students. Female students felt socially more involved with other students than male students, and these results were statistically significant (**Figure 4-a**). White students felt more involved with other students than non-white students; however, the difference was not statistically significant. These results reject the hypothesis that female students and minority students feel more isolated from other students.



**Figure 3.** Average dissatisfaction, importance, and division parameter of questioned factors for students' education focusing on the strengths in College of Engineering at CSU. Numbers listed on the top of bars are division parameter. Factors are sorted based on division parameters.



**Figure 4.** The perceived social involvement of students by (a) gender: male and female; and (b) race: white students and non-white students.

### Potentially Non-Retaining Students

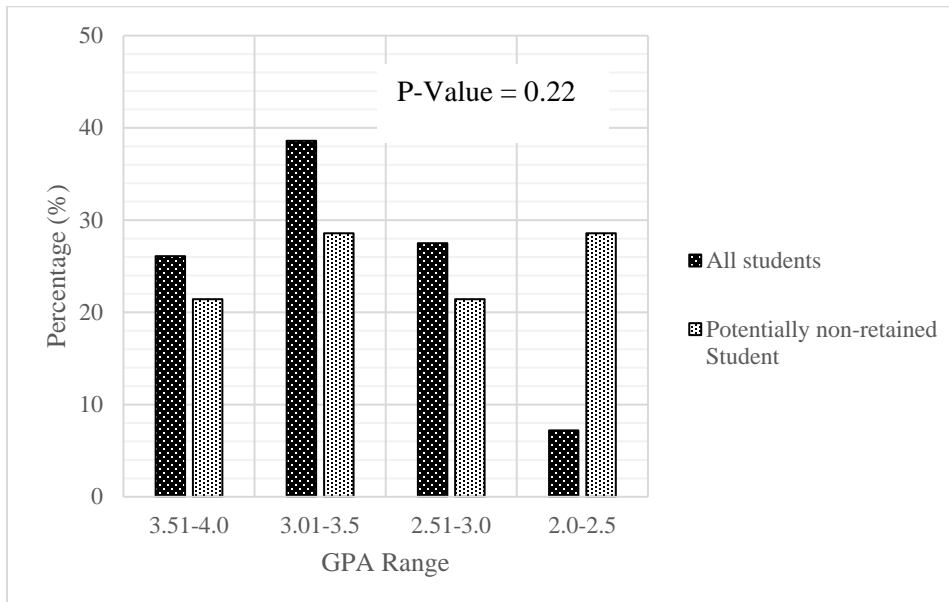
Potentially non-retained students are included students who within the survey, selected, “I have considered/am considering leaving the College of Engineering” and “I plan to leave the College of Engineering, but stay at CSU”. Between potential non-retained students, 40 % of students selected “Hands-on aspect”, “High salary”, “Family pressure”, “I am good at math and science”, and “Heard it was a marketable major/would give me job security” as a reason that

they initially chose engineering as listed in **Table 5**. Economic reasons were more important for potentially non-retained students in comparison with all students.

**Table 5.** A summary of reasons that potentially non-retained students initially chose engineering.

Factors	Number of Students	Percent (%)
Hands-on aspect	6	40.00
High salary	6	40.00
Family pressure	6	40.00
I am good at math and science	6	40.00
Heard it was a marketable major/would give me job security	6	40.00
I wanted to make a positive impact on society through engineering	5	33.33
It sounded enjoyable	5	33.33
Family Encouragement	4	26.67
I participated in engineering related coursework in high school	4	26.67
A family member/friend is an engineer	2	13.33
A guidance counselor told me to go into engineering	1	6.67

The GPA range of potentially non-retained students in comparison with all students participated in the study are shown in **Figure 5**. The GPA of potentially non-retained students varied widely; however, the lower GPA range (2.00-2.50) of potentially non-retained students was larger than that of all students who participated in this study. Statistical test did not show any statistically significant difference between GPA of retained and non-retained students.



**Figure 5.** GPA range of all students and non-retained students. P-value calculated based on Mann-Whitney test

A summary of average evaluation score, importance, multiplication parameter, and division parameter for potentially non-retained students are listed in **Table A-2 in Appendix A**. The least satisfying factors for potentially non-retained students were “the required homework and study hours are too much”, “teaching in my math courses is not engaging”, and “Coursework is too difficult”. The most important factors were “students’ engagement in teaching of math courses”, “Student support”, and “Engagement of students in teaching in engineering courses” for potentially non-retained students. Factors with the highest multiplication parameter for potentially non-retained students are: (i) “Teaching in my math course is not engaging”, (ii) “The required homework and study hours are too much”, and (iii) “Teaching in my physics course are not engaging”, in that order. Factors ii and iii had high Average  $\times$  Importance for all students as well (**Table A-1 Appendix A**).

## Conclusion

An end-of-semester electronic survey was administered to students registered in the *Engineering Mechanics: Statics* course at CSU which 70 % of students are in their sophomore year. From all students who participated in the study, 93 % plan to stay at College of Engineering at CSU, 4 % of students have considered/are considering leaving the College of Engineering, and 2 % of students have already decided to leave the College of Engineering.

- A comprehensive study in literature evaluated top factors that students leave the college of engineering in a multi-year study in an academic institution [2]. Results in their study suggested that the most important factor was lack of belonging to engineering. However, data in this study suggests that most students believe the course work is too difficult and study and homework hours are too much. Another study in literature suggested that student’s grades are the most important academic factor that shows students’ tendency to stay in their education [9]. Our study suggested that the potentially non-retained students had a lower GPA in comparison with the retained students; however, the GPA difference was not statistically significant.
- Primary reasons that students selected engineering were “they were good at math and science” and “they wanted to make a positive impact on society through engineering”. However, potentially non-retained students come to engineering because of “hands-on aspect”, “high salary”, “family pressure”, “I am good at math and science”, and “heard it was a marketable major/would give me job security”. From these responses, it can be concluded that economic reasons played a more important role in engineering selection for potentially non-retained student.
- Social involvement of students was investigated to examine the interaction of students. Ethnicity did not play a significant role in social involvement of engineering

students; however, female students were more socially involved in comparison with male students.

- The areas of potential improvement to better serve students (using the multiplication parameter - product of highest importance and low satisfaction) could include: “for me, the required homework and study hours are too much”, “coursework is difficult”, and “teaching in my physics courses is not engaging”. The factors with the highest multiplication parameters for potentially non-retained students were “teaching in my math course is not engaging”, “for me, the required homework and study hours are too much”, and “teaching in my physics courses is not engaging”.
- These factors were important and satisfying for students (low division parameter) which determined as strengths of the program: “teaching in my engineering courses is engaging” and “engineering instructors are approachable”.

Generally, students’ primary reason for having selected engineering was due to their personal intellectual capacity and the positive societal implications of engineering as a discipline; however, it appears that outside recommendation did not play an important factor in students selecting engineering. In general, most students believed that course work is too difficult and study hours and homework are too much. Generally, these expressions were stronger for students with lower GPAs. Students found their engineering courses considerably more engaging than the science course.

Future improvements could include:

- data was self-reported and not validated with university databases
- The 25% of students which did not complete the survey are hypothesized to have a higher likelihood of leaving engineering soon due to their disengagement in the course assignments. This could be tested in the future by following adding a longitudinal component wherein students are identified

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## Appendix A

**Table A-1.** Summary of average evaluation, importance, multiplication parameter (Average  $\times$  Importance), and division parameter (Average  $\div$  Importance) of factors for all students in the study.

Factors	Score 1	Score 5	Average Evaluation	Average Importance	Multiplication Parameter	Division Parameter
Class sizes are	Too small	Too large	3.53	3.11	10.95	1.14
Coursework is	Too Easy	Too Difficult	3.65	3.66	13.37	1.00
Math and science courses at CSU are _____ to my engineering coursework	Totally relevant	Not relevant	2.27	3.59	8.13	0.63
For me, the required homework and study hours are	Too little	Too much	3.70	3.82	14.10	0.97
Teaching in my engineering courses is	Very engaging	Not engaging at all	2.39	4.33	10.35	0.55
Teaching in my chemistry courses is	Very engaging	Not engaging at all	3.42	3.47	11.86	0.99
Teaching in my math courses is	Very engaging	Not engaging at all	3.14	3.99	12.53	0.79
Teaching in my physics courses is	Very engaging	Not engaging at all	3.32	3.87	12.86	0.86
Overall I find my coursework	Very engaging	Not engaging	2.65	4.09	10.82	0.65
Engineering is what I expected	Totally agree	Totally disagree	2.59	NA	NA	NA
Student support is	More than enough	Not nearly enough	2.65	4.01	10.65	0.66
I feel _____ other students	Involved with	Isolated from	2.65	2.09	5.52	1.27
Engineering instructors are approachable	Totally agree	Totally disagree	2.11	3.37	7.12	0.63
Chemistry instructors are approachable	Totally agree	Totally disagree	2.90	2.64	7.67	1.10
Math instructors are approachable	Totally agree	Totally disagree	3.20	3.16	10.13	1.01
Physics instructors are approachable	Totally agree	Totally disagree	3.12	2.89	9.02	1.08
Engineering classes at CSU are hands on	Totally agree	Totally disagree	2.88	3.33	9.60	0.86
I really like to have official entrepreneurship classes	Totally agree	Totally disagree	2.57	NA	NA	NA
Mentoring program at CSU is _____	Sufficient	Not Sufficient	3.00	2.64	7.93	1.14
Number of students in each classroom is	Sufficient	Too many	3.03	2.32	7.03	1.31

**Table A-2.** Summary of average evaluation, importance, multiplication parameter (Average  $\times$  Importance), and division parameter (Average  $\div$  Importance) of factors for potentially non-retained students in the study.

Factors	Score 1	Score 5	Average	Importance	Multiplication Parameter	Division Parameter
Class sizes are	Too small	Too large	3.71	3.14	11.67	1.18
Coursework is	Too Easy	Too Difficult	3.93	3.64	14.31	1.08
Math and science courses at CSU are _____ to my engineering coursework	Totally relevant	Not relevant	2.86	3.71	10.61	0.77
For me, the required homework and study hours are	Too little	Too much	4.21	3.79	15.95	1.11
Teaching in my engineering courses is	Very engaging	Not engaging at all	2.79	4.43	12.34	0.63
Teaching in my chemistry courses is	Very engaging	Not engaging at all	3.64	3.21	11.71	1.13
Teaching in my math courses is	Very engaging	Not engaging at all	3.93	4.57	17.96	0.86
Teaching in my physics courses is	Very engaging	Not engaging at all	3.43	4.21	14.45	0.81
Overall I find my coursework	Very engaging	Not engaging	3.21	4.21	13.55	0.76
Engineering is what I expected	Totally agree	Totally disagree	3.71	NA	NA	NA
Student support is	More than enough	Not nearly enough	2.86	4.50	12.86	0.63
I feel _____ other students	Involved with	Isolated from	3.21	2.00	6.43	1.61
Engineering instructors are approachable	Totally agree	Totally disagree	2.14	2.00	4.29	1.07
Chemistry instructors are approachable	Totally agree	Totally disagree	3.00	2.50	7.50	1.20
Math instructors are approachable	Totally agree	Totally disagree	3.64	2.00	7.29	1.82
Physics instructors are approachable	Totally agree	Totally disagree	3.21	2.29	5.22	1.41
Engineering classes at CSU are hands on	Totally agree	Totally disagree	3.57	1.50	2.25	2.38
I really like to have official entrepreneurship classes	Totally agree	Totally disagree	2.43	NA	NA	NA
Mentoring program at CSU is _____	Sufficient	Not Sufficient	3.29	2.43	5.90	1.35
Number of students in each classroom is	Sufficient	Too many	3.21	3.00	9.00	1.07