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Evaluating Student Project Ranking in an Industry-Sponsored Multidisciplinary Capstone Program to Improve Student Placement and Project Proposals

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This study stems from an industry-sponsored capstone design program where students work in multidisciplinary teams for two semesters. The process of placing students on teams is critical to ensuring students are successful in the program and project results meet sponsor expectations. Students are placed on teams by the program staff based on a project ranking survey they must submit after attending presentations about each project. These presentations are given by the faculty who will coach each project. The main survey questions are to rank the projects based on their preferences and skills. This study evaluates the project presentations and survey results from four years to explore the following questions: (1) How much effort do students place on project placement? (2) What type of features have the most impact on students when ranking projects? (3) Which engineering features make projects engaging? In answering these questions, this study defines a measure for quantifying effort and uses a mixed-methods analysis of the data that explores creating a framework for automatic quantification of student interests. The methodologies introduced in this paper can help sponsors and faculty propose more compelling projects and provide insight to improving academic-industry collaborations. The results presented will help the capstone program improve the guidelines for students to complete the survey and increase their opportunities of being placed on the project of their choice.

Keywords: multidisciplinary, capstone design, project selection, industry sponsored

Introduction

In multidisciplinary engineering capstone courses, students of various engineering disciplines work in teams to complete design projects. Projects are either provided by the course or proposed by the students. When forming the student teams, courses have employed a variety of methods including student self-assigning, random assignment, faculty placement based on either project needs, student interest and student fit within the team, faculty placement based on their own preferences, and even automated software which groups students based on their preferences and skillsets. Research in the field of capstone courses has shown most advantages for team success occur when team formation allows for student preference and balancing student skills and abilities [1],[2]. To obtain student preference, courses usually employ a survey to obtain student information and preferences. This study examines the process of students providing their preferences after learning about the available projects.

This study stems from a well-established capstone design program where students work in multidisciplinary teams for two semesters in planning, designing, building, and testing projects provided by industry, academic and service sponsors. In this program, students are placed in teams by the program staff, based on their responses to the course Project Ranking Survey (PR Survey), which they complete after learning the descriptions of each project. The staff has two goals when assigning students to projects. First, that projects have the ideal talent for success, as identified by the coach, and second, that overall student satisfaction is maximized. Staff also consider many variables regarding student fit such as their schedules, previous experience, and course expectations.

This study analyses four years of results from the PR Survey to describe how students responded to the project pitch presentations and evaluate their effort towards project placement. The goal is to improve this process with respect to helping sponsors and faculty attract students through their projects and presentations. The further goal is to build a framework for automatic quantification of student interests. Recognizing student interest would help sponsors and capstone staff define compelling projects and provide insight to improving academic-industry collaborations. The results of this study should also lead to improving the PR Survey and the guidelines for students to complete the survey to increase their opportunities of being placed on the team of their choice.

Literature Review

Team forming in capstone courses has been studied at large, with student fit based on several variables, with results showing that it is a complicated problem with no easy solution [1],[2]. A 2015 study on capstone courses in the U.S. found that the most common way to assign students to projects was student choice, followed by instructor choice and student skills. Many respondents stated they utilized a combination of options, also including factors such as GPA and student schedules, and many often used a software solution to automate the task [3]. As many programs must deal with large numbers of students, this process of deciding how to place students in projects has been studied as the student-project allocation problem, with many proposed solutions based on various premises [4] - [6]. With all these algorithmic solutions, while they are designed to optimize team formation with respect to potential success, the underlying problem is helping staff with the complicated task of placing students.

There is a fair consensus amongst the faculty in the capstone design community that to attract students, projects must be *cool* in the sense of involving technology that is familiar to them and worthwhile [7],[8]. Two papers were found that asked students from capstone courses to evaluate the project selection process. The first paper, with results from surveys in 2006, had 66 engineering capstone students rate a list of activities related to project selection [9]. Their results showed that most respondents read through all the project descriptions and select projects based on their interest in the related field. These also show a preference for faculty giving short presentations of the projects they would be advising.

The second paper, from a 2015 study, had 83 students from electrical, mechanical, and biomedical engineering, rate 14 pre-determined factors on how important these were for them when choosing capstone projects [10]. Their results show that the most important factors were: (1) obtaining engineering experience in a particular field or technical area, (2) gaining exposure to a company for employment opportunities, (3) working on a project sponsored by industry, (4) quality of the project pitch, and (5) knowledge on the project technology. The background and methodology of the project selection process described by these authors is similar to the process described below for this study, and fairly common in the engineering capstone community based on the literature review and anecdotal conversations in events such as the Capstone Design Conference [11].

To evaluate student performance when completing the PR Survey, it is necessary to quantify the effort they place on the task. While effort is not a widely accepted definition for quantitative analysis, it has been included in definitions of academic motivation as "the ability of the learner to persist with the task assigned, the amount of time spent on the task, the innate curiosity to learn, the feelings of efficacy related to an activity, or a combination of these variables" [12]. Meltzer, et.al. defined student effort as a conscious attempt to achieve a particular goal through persistence over time [13]. The definition of effort for this study must reflect the amount of work done in the PR Survey for their attempt to be placed at their project of preference, where a significant amount of that should go towards describing the expected contributions for project success. Therefore, following the literature above, effort in this study is quantified by three factors from the students answers on why they want to be placed on a project. These factors are (1) the relative length of their answers, (2) the correlation between their answers and the respective project pitch, and (3) whether they included mention of their engineering skills with respect to the project needs.

Research Questions

This study presents the evaluation of the results of the student project ranking process for one multidisciplinary capstone design program over four years, to share insight on the following research questions.

1. How much effort do students place on project placement?
2. What type of features have the most impact on students when ranking projects?
3. Which engineering features make projects engaging?

Rather than surveying students to reflect on the process, this study evaluates the actual responses students submitted by the students for the project ranking process.

Context and Data Collection

The data for this study was collected data from the University of Florida (UF) Integrated Product and Process Design program (IPPD), which offers a two-semester team-based multidisciplinary capstone design course [14]. All senior undergraduate students in the Herbert Wertheim College of Engineering are eligible to participate in the program [15]. The college offers thirteen engineering bachelor’s degrees, plus computer science, and digitals arts and sciences. Reference [14] lists the program’s projects and descriptions. Most team have had four to six students.

Table 1 shows the number of projects and students for each year of data for this study. The number of students in the table refers to those who completed the PR Survey and were placed in a project. Use of this data for the study was approved by the UF Institutional Review Board.

Table 1. Data for this Study: Number of Projects and Students for 2019 – 2023

Academic Year	Students	Total projects	Number of Unique and New Sponsors
2019 – 2020	47	13	13 (all assumed new for year 0 of study)
2020 – 2021	55	14	13 unique, 6 new
2021 – 2022	59	11	10 unique, 3 new
2022 – 2023	79	18	17 unique, 8 new
Total	240	56	30

On the first day of class, the faculty advisor for each project gives a *pitch presentation* of their one or two projects, followed by a short Q&A session. The presentations use a standard template, and coaches do not compare projects or suggest unique workload expectations. The standard template of the pitch presentation slides with a pseudo-example is illustrated in Figure 1. Each project pitch slide is encoded with a set of descriptive Engineering Keywords specific to the project. "**Engineering Keywords**" are defined as words related to engineering theories, technologies and skills related to executing engineering tasks. The authors of this study manually extracted up to 15 Engineering Keywords from the pitch slide of each project listed in Table 1.

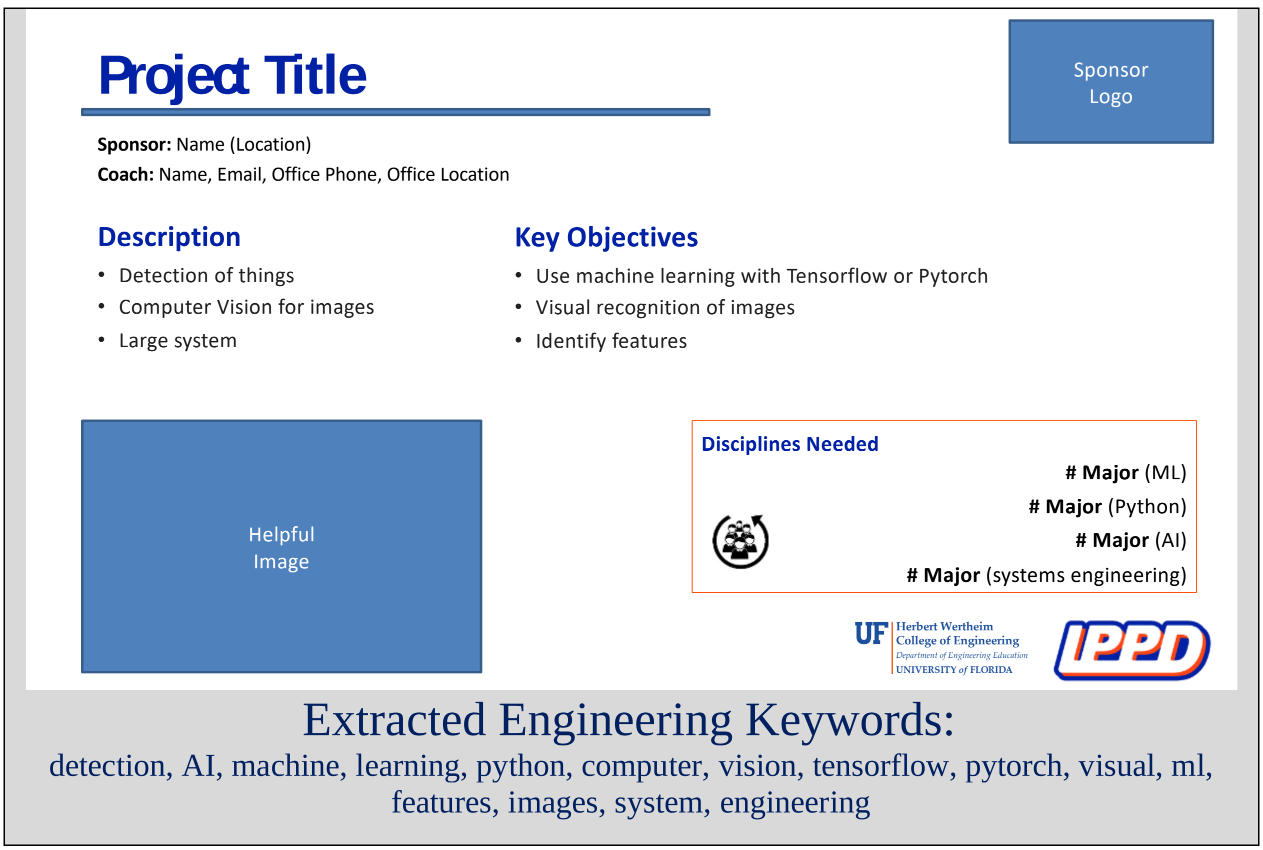

Figure 1: Example of keywords extraction from a project pitch slide.

Before the presentations start, students receive the Project Ranking Survey (**PR Survey**), which the program faculty use to assign the team for each project. The surveys are not graded, but all students must submit it for team placement. Students have until the end of the day to review the presentations and their notes and submit the PR Survey. Students are encouraged to rank a minimum of three projects, as most will be placed in any of those three, and to be thorough in their answers to support their placement case. Therefore, most analysis done in this paper is based on students' Top 3 ranked projects.

The PR Survey includes a list of all the projects for the year, with two text entries for each, one to place a ranking number, and the other to "… describe why you are qualified for that project and why it interests you." This description is optional but highly encouraged. These answers were used for all the analysis in this study, hence so forth all mention of **Student Responses** refers to these answers.

To quantify student effort, the Student Responses are compared with the Engineering Keywords to compute factor (2) Engineering Keywords Correlation (EKC). This factor is computed automatically by counting how many keywords the students' answer has in common with those encoded for each project (example in Figure 1). The score is normalized by the total number of keywords in each project; maximum and mode of 15, average of 14.5.

Another effort quantifier is factor (1) Relative Answer Length (RAL) of the Student Responses, after disregarding words in the defined stop list and normalizing the score by the maximum length from each respective academic year. The stop list contains the most common words in the English language, such as articles, pronouns, prepositions, adverbs, conjunctions, interjections, unions, proper names, introductory words, numbers from 0 to 9 (unambiguous), other frequently used official, independent parts of speech, symbols, punctuation, and Internet sequences of symbols (as www, com, http, etc.). The stop list is available for download at the link provided after the References section.

For the third effort quantifier, the authors inspected the Student Responses to identify if their answers explicitly mentioned or not any qualification for joining that project. That is, did they state an engineering related knowledge or skill they had that would meet a need for the project. The results were tabulated as a binary value.

The survey includes additional descriptive questions, but these were not used for this study. The survey includes various objective questions for student identification and academic standing. Identifying information was coded before this study to preserve anonymity. Academic data such as student GPA was analyzed with respect to the EKC and RAL data.

Methodology

This section is organized by research question.

RQ1: How much effort do students place on project placement?

This question is analyzed using the Student Responses for their top 3 ranked projects. For this evaluation, effort was measure through a combination of:

a) The RAL of all Student Responses for the respective year.
b) The EKC between each Student Response and the Engineering Keywords from each respective slide from the project pitch activity.
c) Whether they mentioned or not any qualification for joining the ranked project.

Each effort element was analyzed independently, then aggregated for an overall analysis.

RQ2: What type of project features have the most impact on students when ranking projects?

For this question, Student Responses are analyzed to determine the frequency with which students mention features that attracted them to the projects. The features were defined as:

- Engineering – using the same RQ1 definition for qualification, i.e., if they stated an engineering knowledge or skill they had that would meet a need for the project.
- Tech – if they expressed an interest in the technology associated to the project.
- Sponsor – if the student expressed interest in working with the sponsor of the project.
- Faculty – if the student expressed interested in working with the project coach.
- Personal – if the student described personal reasons for their interest.

The results are calculated per year and combined for an overall analysis.

RQ3: What engineering features make projects engaging?

This question is approached through a longitudinal analysis to evaluate the most cited engineering words students use when describing their qualifications and interests for ranking projects. Engineering words are any words that relate to the field of engineering. For this question, only the answers for their number one top ranked project were considered. These answers for all the years were combined and grouped by each student's academic major.

Through the mixed-methods analysis of the data, this study also explored creating a framework for automatic quantification of student interests. The basis of this framework is a bag-of-words (BOW) system that considers the longitudinal Student Response answers and builds a dictionary of 1-, 2- and 3-gram keywords. The BOW is trained to disregard words included in the defined stop list. This system utilizes the longitudinal data from Table 1, and it can be retrained as more data is collected allowing for the continuous learning of a student keywords dictionary.

Results and Analysis

This section is organized by research question.

RQ1: How much effort do students place on project placement?

Figure 2 shows a histogram of the number of EKC by academic year (AY) and by ranking number. No significant changes in the students' use of Engineering Keywords are evident when comparing from year to year or from rank to rank. This suggests students are mentioning keywords at the same rate regardless of the rank of the project.

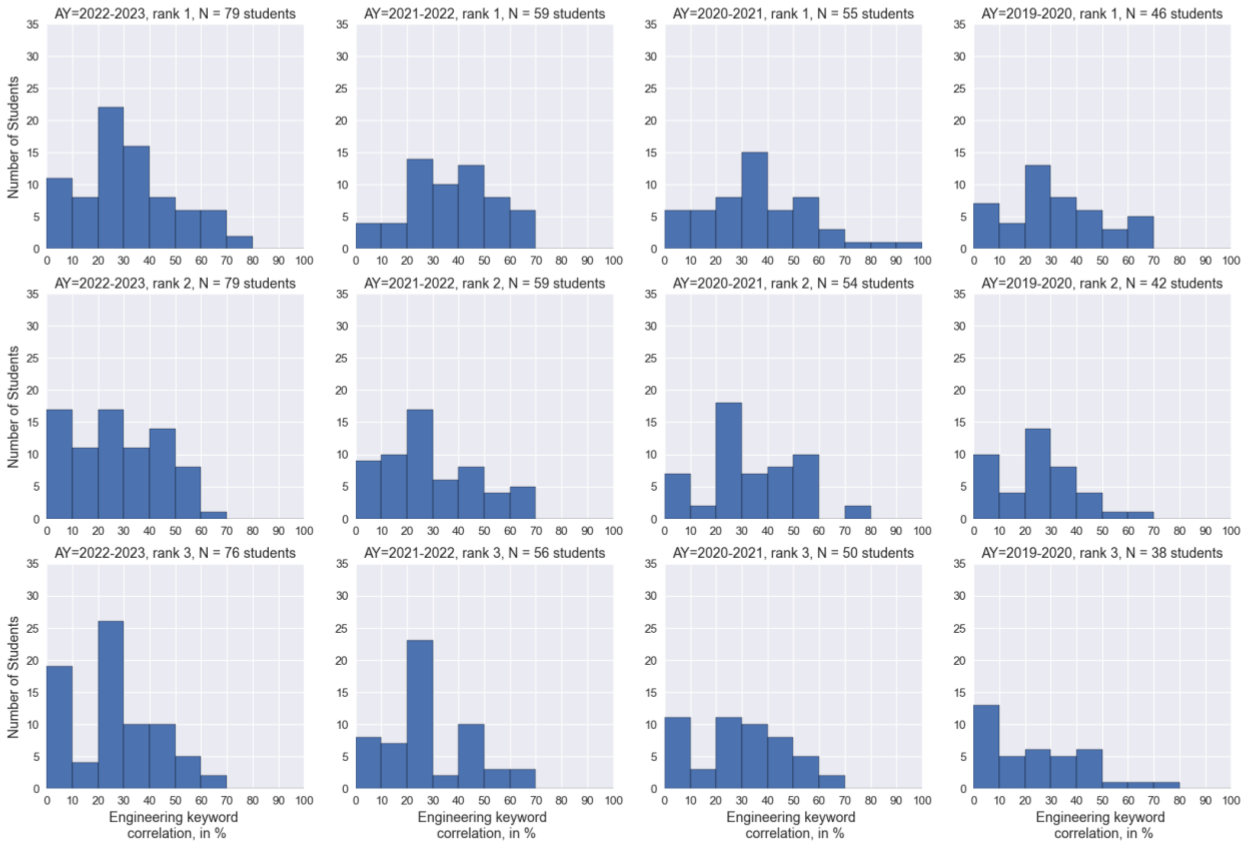

Figure 2: Histogram of EKC by Year and by Ranking Number

Figure 3 shows a histogram of the RAL of the Student Responses distributed by academic year and by ranking number. Figure 3 shows that Student Response length decreases with the rank of the projects for every year. These results show that for projects ranked 1 over the four years, 44% of students cited 3 to 6 of the Engineering Keywords used for calculating the EKC, 35% of students cited more than 6 Engineering Keywords and 21% wrote less than 3. For projects ranked 2 and 3, about 30% of students used less than 3 Engineering Keywords and about 21% wrote more than 6. Evidently, their effort regarding tying their qualifications and skills with the project descriptions decreases with their ranking preferences. That is, students are less likely to write long answers for interests and qualifications of the projects for their 3rd ranked projects than their top project.

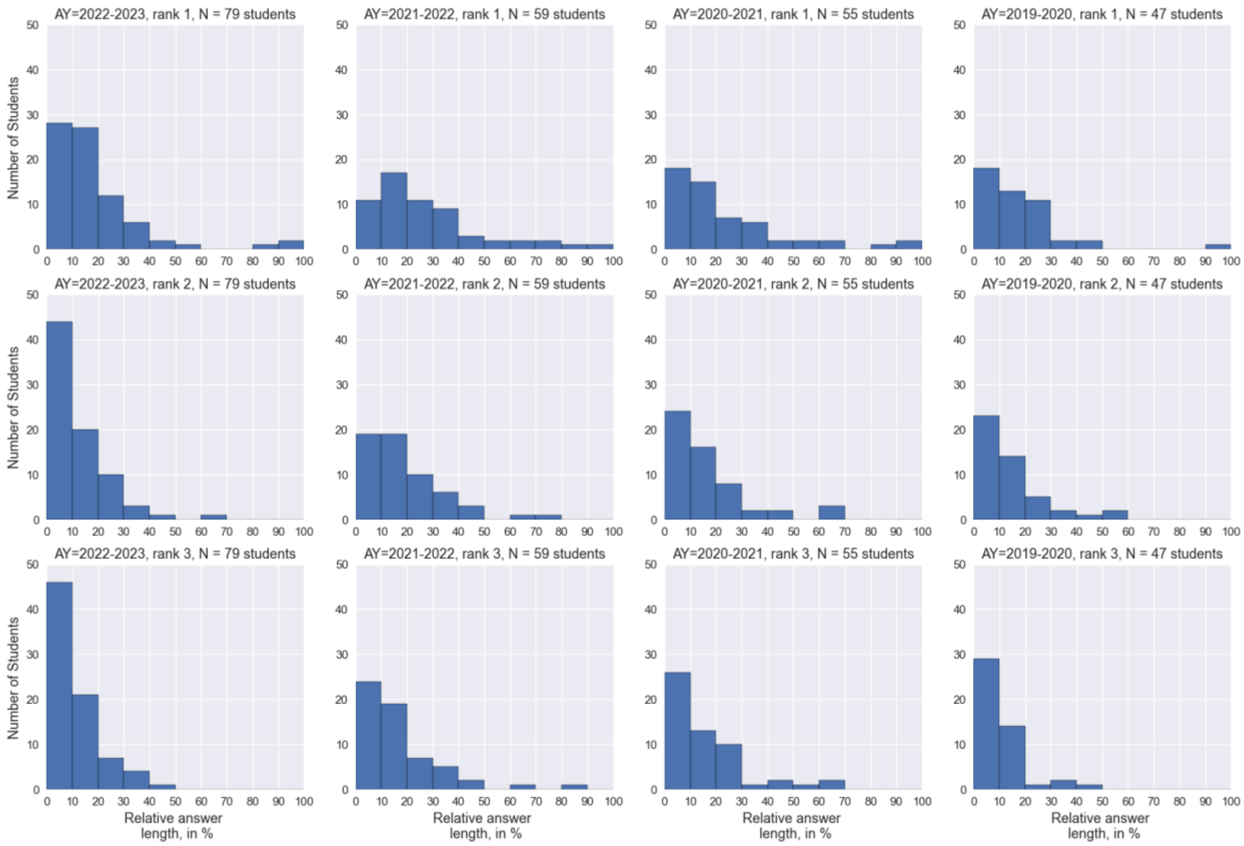

Figure 3: Histogram for the RAL of the Student Answers by Year and by Ranking Number

While the word count increase year-to-year could be a coincidence, it is likely the reason why more of the data are categorized into lower percent in 2022 when compared to the other years. To assess effort, Table 2 shows the contrast between the maximum number of words for each year (not including words from the stop list as defined for the RAL) and the median RAL for rank 1 selections. While the maximum RAL has increased each year, students overall have written less in comparison to each respective maximum.

Table 2. Maximum and Median RAL of Student Responses for Rank 1 Selection

Academic Year	Maximum RAL	Median RAL
2019 – 2020	79	10
2020 – 2021	90	13
2021 – 2022	118	21
2022 – 2023	125	17
Total	240	56

Figure 4 shows the median of EKC score as a function of the student project choices in their rankings. The projects are grouped by number of votes received, i.e., the number 1 and 2 Project Votes refers to the projects that received 1 or 2 votes that year, the number 3 through 5 refers to the projects that received 3 to 5 votes, and similarly, label “>8” refers to the most popular project with more than 8 votes (if that occurred) in number of rankings.

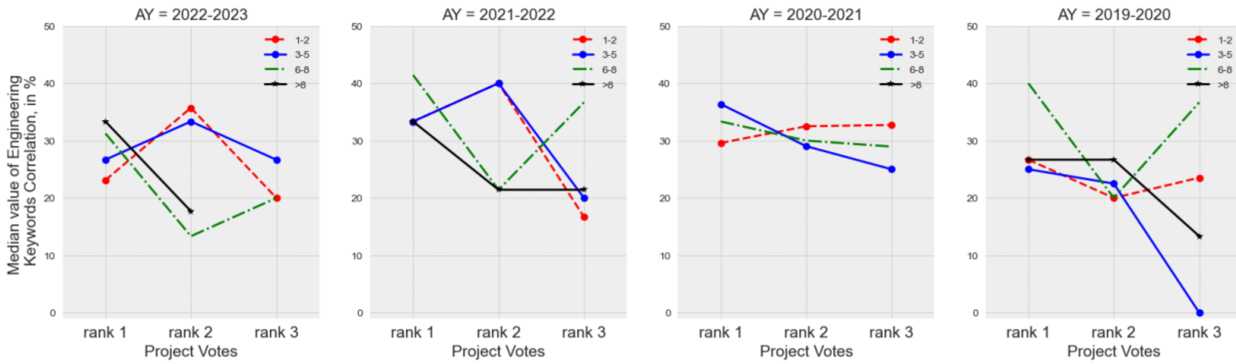

Figure 4: Median of EKC versus Student Interest in Joining each Project

The results from Figure 4 do not show a clear pattern. The “>8” projects, those with the most amount of student interest, did not have the highest EKC on any year. The data shows that interest in the most popular projects is not a determinant for student effort when supporting their ranking choices.

The data was also analyzed with respect to the students’ GPA at the time when they completed the PR Survey. Figure 5 shows the correlation between GPA and the EKC shown in Figure 2. The data for only two of the subplots, rank 1 for AY 22-23 and rank 1 for AY 20-21, showed statistical significance, which suggests in these two cases there was a positive correlation between the students’ GPA and the amount of Engineering Keywords they used to support their number one ranked project. However, no overall trends are noticeable.

Figure 6 shows the correlation between GPA and the Student Response RAL shown in Figure 3. Like in Figure 5, there does not appear to be a correlation between the RAL and the students’ GPA. Therefore, between the results in figures 5 and 6, it is clear that student GPA is not a predictor of the effort students will place in project ranking.

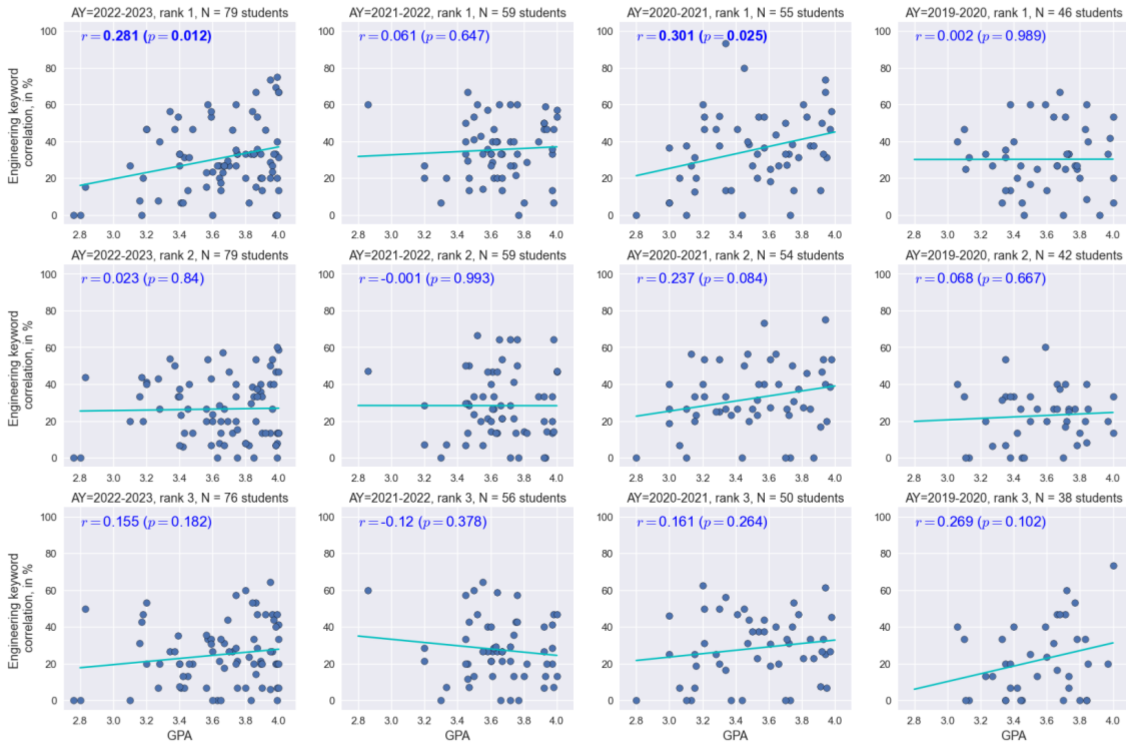

Figure 5: Correlation between Engineering Keywords and Student GPA, by Year and by Ranking Number. *r* is Pearson's correlation and *p* is the p-value.

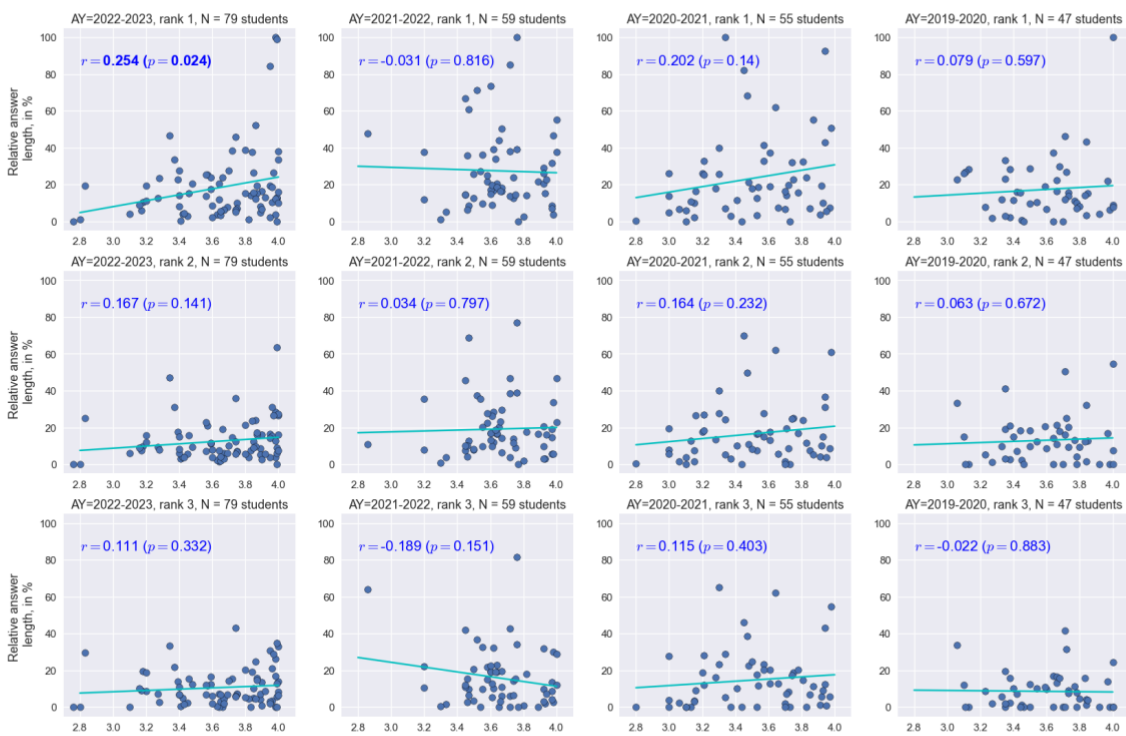

Figure 6: Correlation between Relative Length of the Student Answers and Student GPA, by Year and by Ranking Number. *r* is Pearson's correlation and *p* is the p-value.

Figure 7 shows that the EKC increases with RAL but does not appear to change much from year to year or from rank to rank. From a probability perspective, if students are writing longer responses, increasing the number of words of a Student Response will increase likelihood of having more EKC in the response. Across all years and ranks, it appears the length threshold for which at least one keyword is in the response is about 10% length. This suggests that if students are writing more, they are going to use EKC in their responses and, therefore, put in effort to list their qualifications and interests with respect to mentioning EKC for the project. Conversely, we do not see students writing long Student Responses without using any or few EKC.

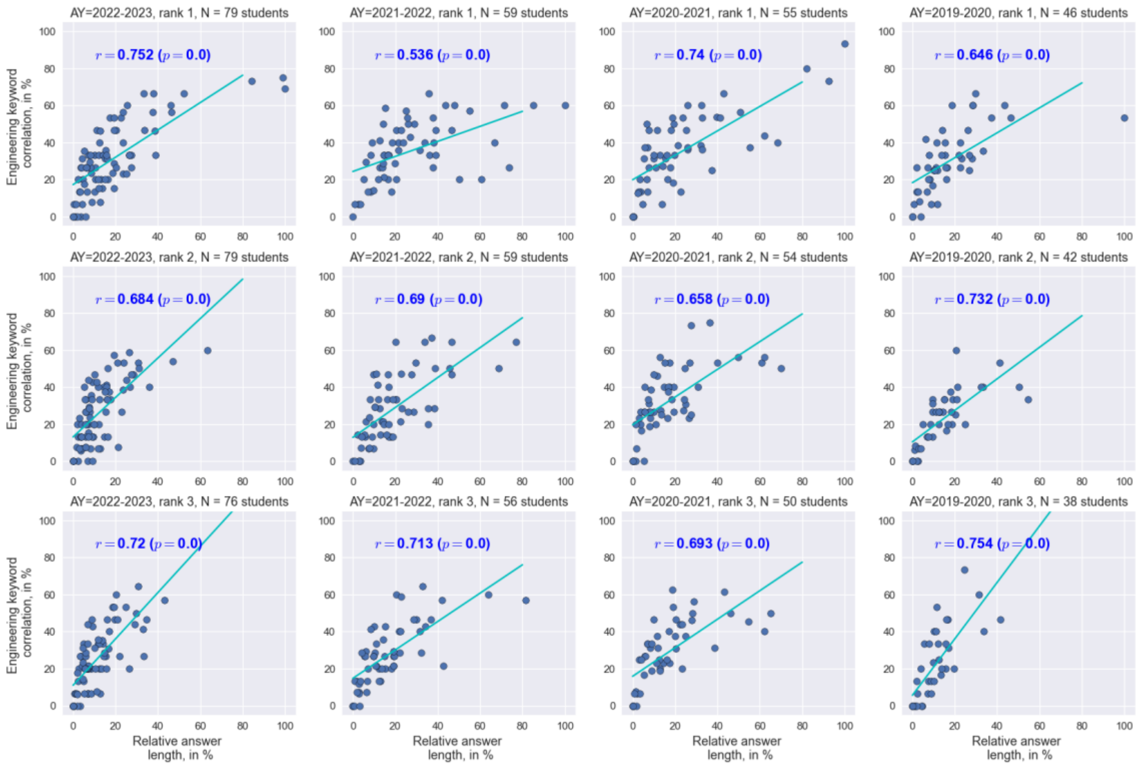

Figure 7: RAL of Student Responses versus EKC by Year and by Rank

The analysis of whether students mentioned or not any qualification for joining the ranked project, showed that over the four years 93% of students mentioned a qualification in at least one of their rankings. Such a high number is an indication that mentioning engineering skills is not a significant factor in determining the effort students put into their answers. Further analysis will be done to determine any pattern of these mentions with respect to the results shown above, to help evaluate an effort score by student, by ranking and by type of project.

RQ2: What type of project features have the most impact on students when ranking projects?

The results of the count of project features over the years are shown in Figure 8. The results are displayed as the percentage calculated by dividing the total count for each category by the total number of student rankings per year. For example, in 2019 if all 47 students had completed the top 3 rankings, then the denominator would be 141, however, the denominator is 128 given some students ranked less than three projects. Therefore, the 88 mentions of Engineering skills for 2019 is represented by 88/128 = 69%, that is, the 2019 students mentioned their qualifications for joining a project in 69% of their top 3 rankings.

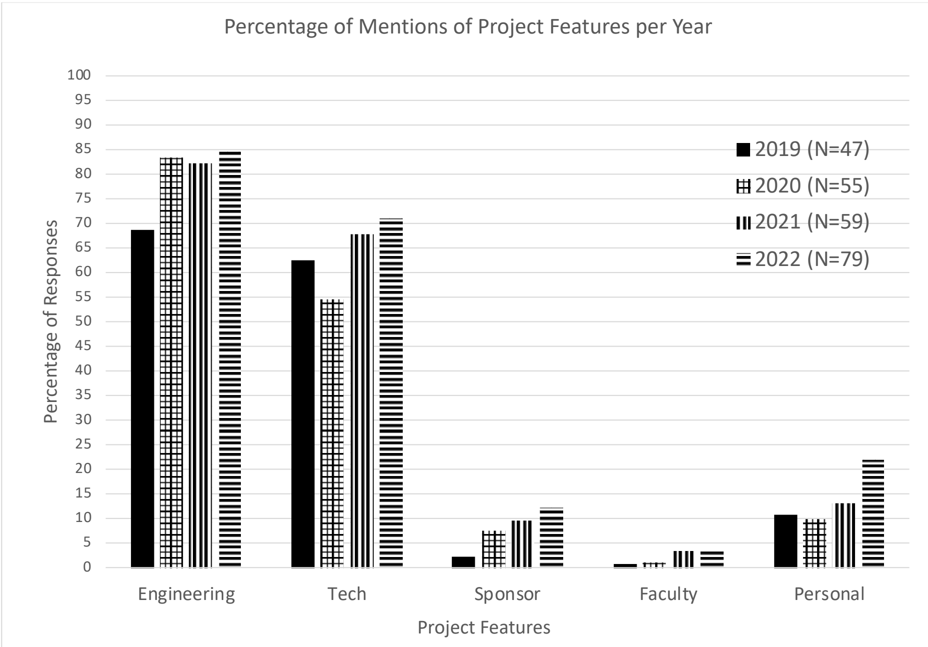

Figure 8: Percentage of project feature mentions out of all project rankings. N is the number of students who completed the survey each year.

The results show that students overall are most likely to mention their engineering skills when answering their interest and qualifications related to their ranking choices. Most students also described an interest in the technology related to the projects. While these results have shifted year to year, there is not a significant change. Therefore, as students were told that their qualifications and interests would be strongly considered during project placement, most students will focus on qualifications, while for interests they will mostly consider the technology involved regardless of the sponsor or the faculty advisor.

The sponsor category showed growth over the years with a jump from 2% to 12% over the period. Similarly, the personal category significantly increased over the years. Analysis done with similar data for a concurrent study showed that this growth is driven in large part by an increase in non-industry sponsors, who more students relate to through a personal connection with the sponsor or the project theme [16].

RQ3: What engineering features make projects engaging?

Given the imbalance in academic majors, the results only include majors that had at least 10 students over the four years. Keywords included in this analysis were listed by a minimum of 40% of students. The majors and keywords are listed in Table 3.

Table 3: Keywords Mentioned by 40% or more of Students grouped by Academic Major

Major	Keywords in order of decreasing mentions
Biomedical Engineering (BME)	learning, machine learning, python, bme, matlab
Computer Engineering (CPE)	software, embedded, programming, design, robotics, systems
Computer Science (CS)	software, learning, development, machine learning, python, web, engineering
Electrical Engineering (EE)	design, pcb, ee
Mechanical Engineering (ME)	design, mechanical

This analysis provides insight on what students want to say when supporting their ranking choices. From a sponsor perspective, the results may help create projects that will attract more students. By correlating these results with the analysis for the research questions above, it is possible to learn the student interests by majors and the most common engineering skills students are interested in applying and developing. For example, from the results in Table 3:

- EE and ME students make considerable use of the word design versus other majors.
- BME and CS students are highly interested in machine learning, but they are also interested in learning in general, as the word learning was not always associated to machine learning. Further analysis is needed to identify the associated topics.
- EE students are interested in work with printed circuit boards.
- CPE students are interested in software, embedded systems and robotics.
- Most ME students mentioned the word mechanical seemingly to validate their association with the project.

Conclusion

This paper introduces a methodology to evaluate the student project ranking process using the raw data from the student rankings. This methodology was applied to a multidisciplinary capstone program with the goal of improving the project proposals, the ranking process, and student placement in projects. The methodology includes a definition for quantifying student effort that can potentially be developed into an automated procedure. The results for the data described in this paper showed that classic metrics such as student GPA and project popularity are not strong indicators of student effort. Further analysis will help determine overall trends of what inspires students to place effort in rankings.

This paper also introduced methodologies to determine the project features that have the most impact for students when ranking projects and found that students will place the most effort in describing their qualifications, which was expected as they were told qualifications were a strong determinant for project placement. They were also told that their interests in the project would count as an equally strong determinant for placement, and results showed that most students only focus on the technology when describing their interests, followed in small part by interest in the sponsor or other personal reasons.

The final section of the paper showed a methodology for a longitudinal analysis to determine the engineering features students from each engineering major focus on during project ranking. For the data in this study, the results showed some of the topics that students are interested in developing. While the data is correlated to the available project topics over the years, it is not associated to specific projects when accumulated. Therefore, the results will help guide the program in searching for projects that students will enjoy.

Awareness of student interests can help sponsors and faculty propose more compelling projects and provide insight to improving academic-industry collaborations. Understanding how students engage with the project ranking process will help capstone faculty prepare future students to increase their opportunity of joining their ideal project. The procedures and analysis introduced in this paper can help any course with these goals.

Future Work

The authors will continue to develop the data collection and the data processing, to complete a fully automated procedure that would allow yearly analysis of the project ranking process. Such a procedure would eliminate the rigorous time-consuming data processing techniques described in this paper as done by hand by the authors.

For computing effort, as defined in this paper, future iterations will expand the word search to all student open questions. These answers may provide more insight into student preference of projects.

The authors look forward to collaborating with similar course programs to expand the analysis and contrast student behavior and interests.

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* Stop words list available for download at:
https://www.dropbox.com/s/mrufem7cwsqh6ev/stopwords.pdf?dl=0