Student Perspectives on Skills Required in Engineering and Computing Sciences Courses

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Work in Progress: Student Perspectives on Skills Required in Engineering and Computing Courses

Abstract

Engineering and computing students need to be prepared to find solutions to complex problems faced in college and in their careers. Solving these problems requires a variety of knowledge and skills. This work-in-progress (WIP) research aims to answer the following research questions: a) what are the non-technical skills that students perceive as necessary for their success in engineering courses? b) what are the technical skills that students perceive as necessary for their success in engineering courses?, and c) how do the technical and non-technical skills perceived as important vary by student classification (freshman, sophomore, junior, and senior)? This research will guide a discussion on changes needed in first-year engineering courses to align them with the needs of students in upper-level courses.

This WIP research is conducted via a mixed-method study. A survey collecting students' opinions on important technical and non-technical skills to their success in their major-specific 200- or 300-level courses using both Likert-scale questions and open-ended questions was conducted in an R1, land-grant, public university. The survey was distributed to all undergraduate students enrolled in the College of Engineering and 156 valid responses were analyzed. The results of this study are intended to help this institution, as well as other engineering programs, support necessary skills for success in upper-level engineering courses.

Introduction

Engineers must acquire professional and technical skills to meet global demands. Technical skills are highly emphasized in the engineering curriculum; however, technical skills may not be effective unless they are built around non-technical (professional) skills. Professional skills, or soft skills, are career competencies and abilities that help the individual function and perform within a work environment at the highest level. Examples of professional skills include communication skills, teamwork, time management, creativity, work ethic, leadership, conflict management, and stress management, among others.

Professional skills can be taught and reinforced using expository, guided, and active strategies [1]. The integration of such skills in the curriculum can occur via lectures (expository), demonstrations (expository), project work (guided), simulations (guided), role playing (active), brainstorming (active), and coaching (guided) [1]. Engineering students are exposed to soft skills using one of the following three learning methodologies: expository (lectures, seminars, conferences, and demonstrations), guided (discussions, debates, case studies, project work, simulations, mentoring, and workshops), and active learning (brainstorming, role play, games, site visits, outdoor training, and coaching) [1]. Courses have been designed exclusively to support the development of critical non-technical skills, including communication skills and teamwork, in engineering and computer science [2, 3]. However, the alignment of the skills taught in those courses with the needs of students in subsequent courses have not been addressed.

This study is aimed at understanding how the technical and non-technical skills taught in a first-

year engineering program aligns with the needs of students in subsequent engineering and computer science courses. Research questions for this study include, a) what are the non-technical skills that students perceive as necessary for their success in engineering courses? b) what are the technical skills that students perceive as necessary for their success in engineering courses?, and c) how do the technical and non-technical skills perceived as important vary by student classification (freshman, sophomore, junior, and senior)?

Methodology

A mixed method study was used for this research. The survey collected undergraduate engineering and computing students' demographic information and their opinions on technical and non-technical skills essential for student success in upper-level major-specific engineering and computing courses. The student perspective questions were in the format of Likert-scale questions (extremely important as score 5 and not at all as score 1), multiple answer questions (top five skills), and open-ended questions. The study was approved by the Institutional Review Board (IRB).

Purposeful sampling was used to recruit the survey participants. The survey was created in Qualtrics XM. The web link and/or a scannable QR code of the survey was distributed to all undergraduate students enrolled in the College of Engineering in Fall 2023 via college weekly newsletters, Facebook, email invitations from the college Associate Dean of Academics and Student Performance, and flyers posted in the college's main building.

In total, 230 survey responses were received with 156 valid responses after removing duplicated and non-consent submissions. Results were de-identified and analyzed in Microsoft Excel. The data of students' opinions were aggregated by their self-reported academic year (first-year, second-year, third year, and four-year students) to compare any identified trends. Descriptive statistics were computed for quantitative items and reported in this paper, while responses to open-ended questions will be coded for qualitative analysis for future work.

Results and Discussion

Skills assessed in this study were categorized into two distinct categories: technical and non-technical. Both are essential for student success in upper-level engineering and computing courses. Two sets of questions were asked about the various skills. One question asked students to select their top five from a list. The second set of questions asked them to indicate on a Likert scale their opinion of the importance with respect to their success in major-specific courses. The top and bottom important skills reported by students were aggregated by self-reported years and reported in the Top Skills section. Trend changes among students in different years were discussed in the Ranked Skills section.

Top Skills

First-year students' responses on various skills are shown in Figures 1a and 1b. In Figure 1a, it is evident that managing time was identified as the top skill by first-year students, with 80% of respondents selecting it as their priority. Following closely, 66% of students indicated the

importance of working effectively in teams, while self-learning and recognizing the need for lifelong learning tied with applying engineering design process skills, each receiving 40% of responses. The utilization of appropriate computational tools and coding skills, such as Excel, MATLAB, and Arduinos, received the next most important skill with 34% of responses. As shown in Figure 1b, the least emphasized skill among first-year students was the use of proper career planning tools, with only 8% of respondents considering it important. Additionally, presenting ideas using appropriate presentation tools, applying the engineering code of ethics, and conducting a proper literature review were equally valued, with each receiving approximately 11% of responses.

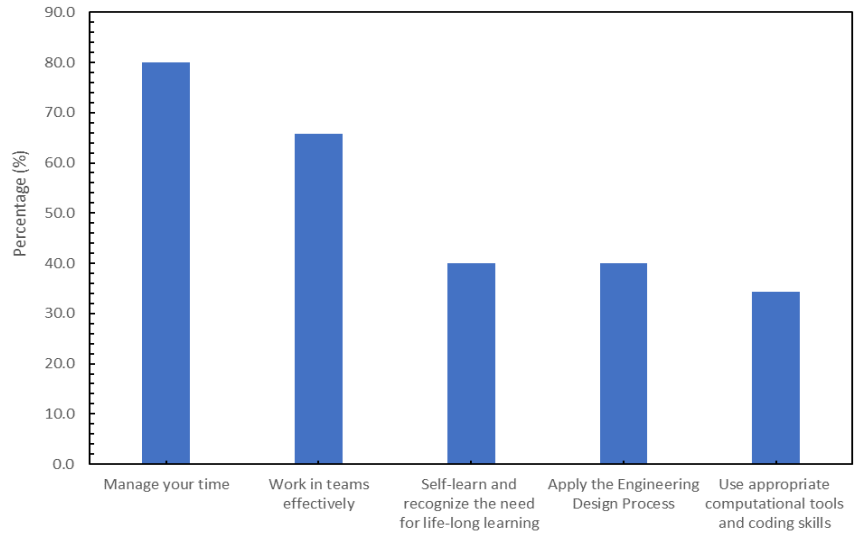


Figure 1a: The first-year top skills

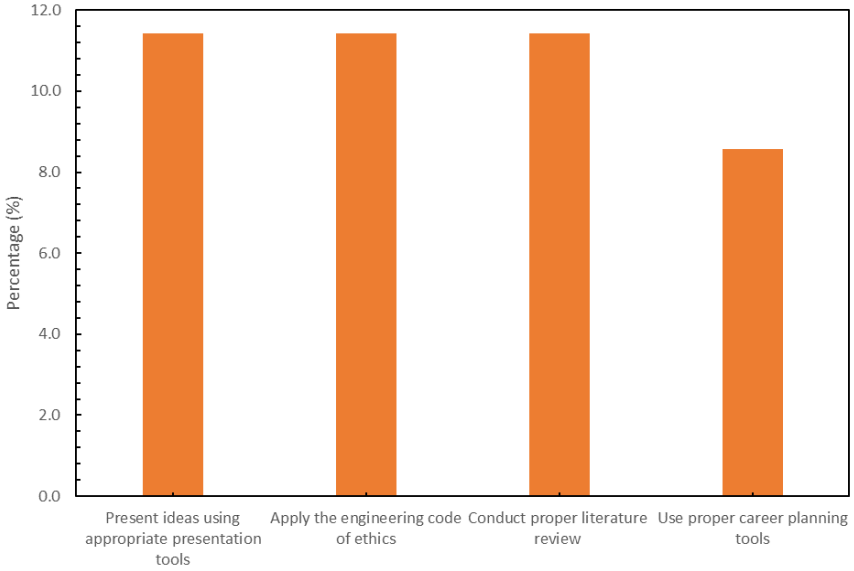


Figure 1b: The first-year bottom skills.

Among second-year students, time management was the most important skill receiving approximately 74% of responses (Figure 2a). Understanding the mathematical language in a problem and self-learning and recognizing the need for lifelong learning received responses of

45% and 43%, respectively. Work in teams, the last top skill, effectively received a response of 31%. In Figure 2b, communicating effectively in writing was selected as the least valued skill from the second-year students, receiving 7% of responses. Applying the Engineering code of ethics and Managing a Project using appropriate project management tools tied for the second lowest important skill with 4.8% of responses. Conducting a proper literature review and Applying the Engineering Design Process tied with 7.1% of responses as the highest of the bottom five skills among second-year students.

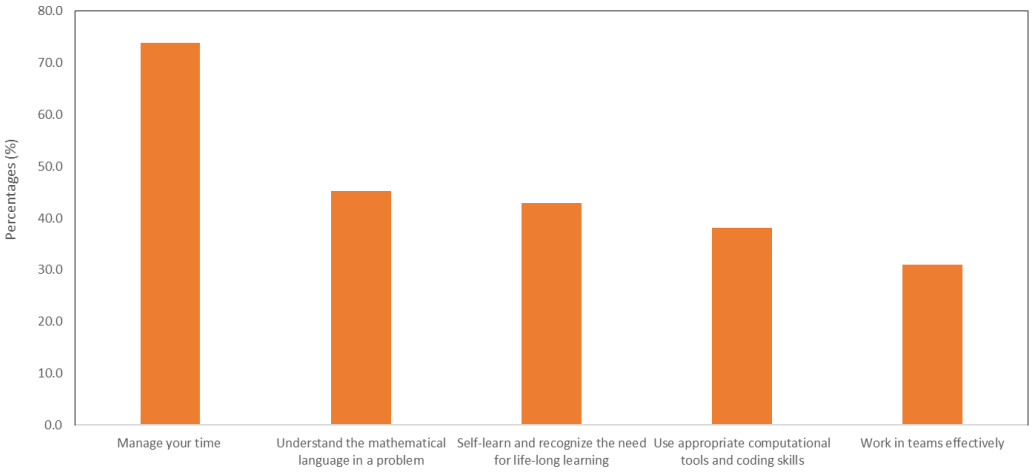


Figure 2a: The second-year top skills.

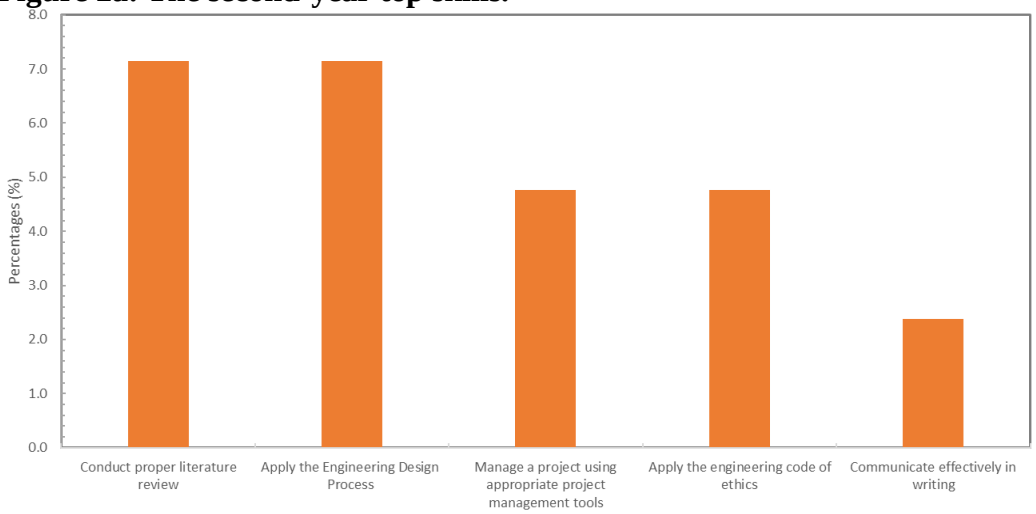


Figure 2b: The second-year bottom skills.

For third-year students, working effectively in teams was the most valued skill, with approximately 78% of respondents selecting it (Figure 3a). Managing time closely followed, with 73% of students indicating its significance. Understanding the mathematical language in a problem and applying appropriate problem-solving steps was the third most selected skill, with 62% of respondents indicating its importance. Using appropriate computational tools and self-learning, and recognizing the need for lifelong learning, were the next ranked skills among the top five, with 48% and 45% of responses, respectively. In Figure 3b, the least emphasized skills among third-year students were managing a project using appropriate project management tools,

presenting ideas using appropriate presentation tools, and analyzing data using statistical methods, each receiving approximately 11% of responses. Using proper career planning tools was deemed the least important skill, with only 5% of respondents considering it valuable.

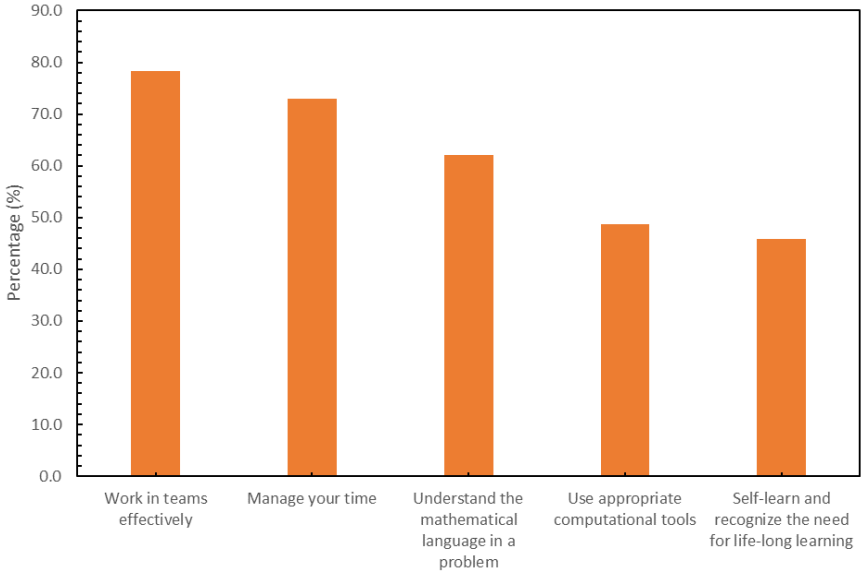


Figure 3a: The third-year top skills.

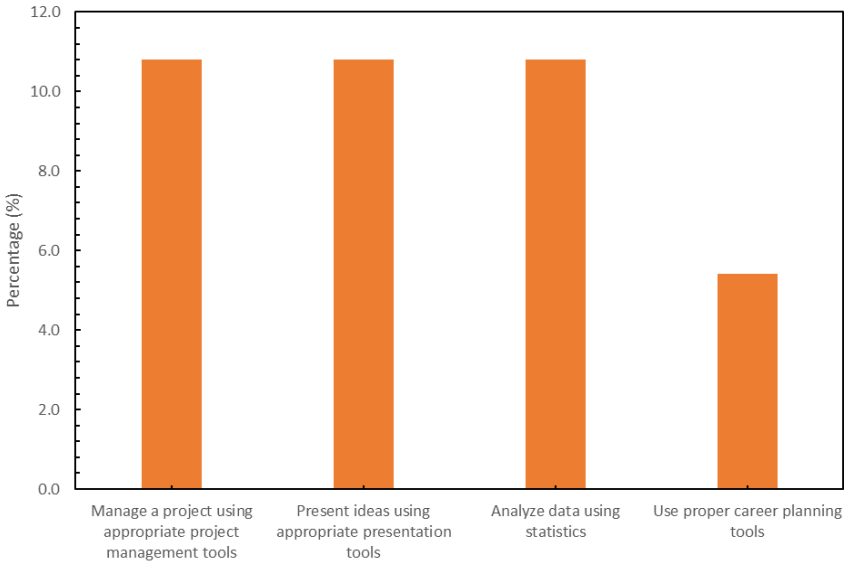


Figure 3b: The third-year bottom skills.

In Figure 4a, fourth-year students indicated working effectively in teams was the most valued skill, with approximately 78% of respondents selecting it. Managing time was selected as the second most important skill, with 70% of the responses. Understanding the mathematical language in a problem and applying appropriate problem-solving steps was the third most important skill, receiving 62% of the responses. Using appropriate computational tools received 60% of the responses, while self-learning and recognizing the need for lifelong learning received 46% of the responses. In Figure 4b, the least valued skill among fourth-year students was analyzing data using statistics with 2.7% of responses. Surprisingly, considering its value in job placement, using proper career planning tools to build a professional presence received only

5.4% of responses, while applying the engineering code of ethics received 8.1% of responses as the most valued skill of the bottom skills..

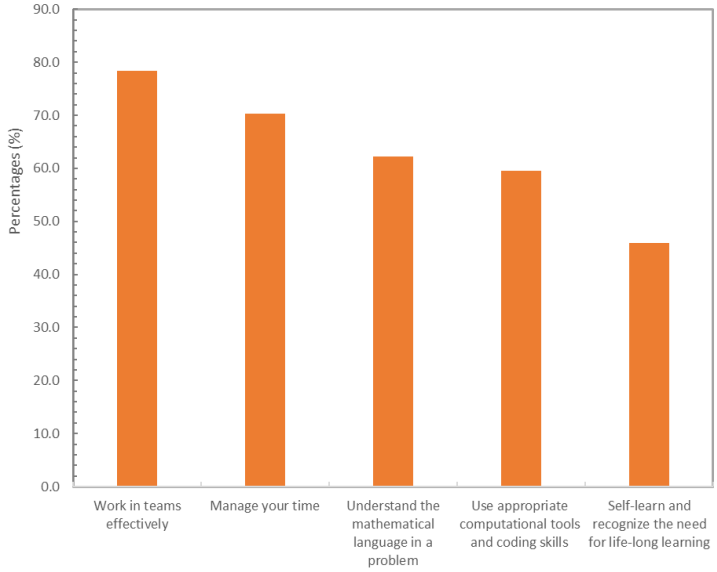


Figure 4a: The fourth-year top skills.

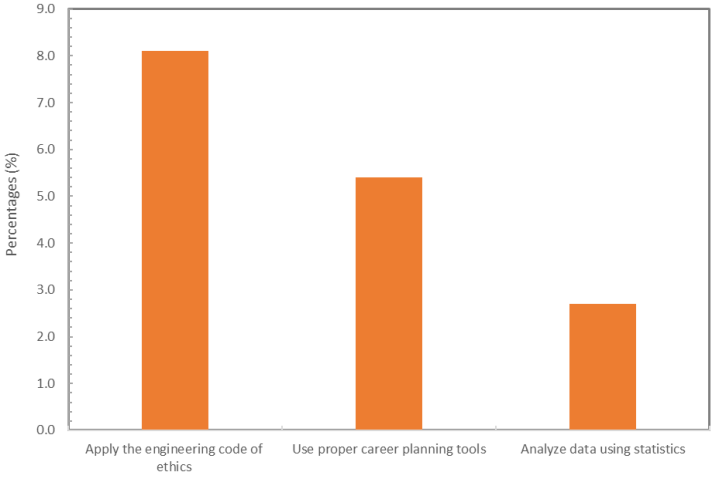


Figure 4b: The fourth-year bottom skills.

Ranked Skills

For Figures 5-8, technical and non-technical skills were investigated to evaluate how the importance of these skills varied by self-reported year in college. An average score of 2.5 or higher on the Likert scale (the vertical axis on each figure) would indicate a higher-than-average level of importance. All of the skills evaluated in all years scored above 3.0, so all of these skills can be considered important by the respondents.

Figure 5 shows how students evaluated the importance of the various technical skills. Over time, understanding the mathematical language in a problem trended upward, especially in the senior year. Estimation techniques and statistics trended downward over the years. Researchers believe this reflects the relative use of these skills by upperclassmen.

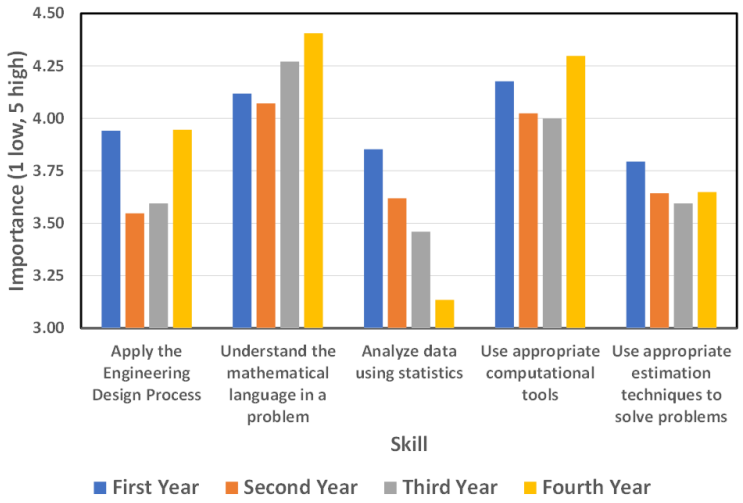
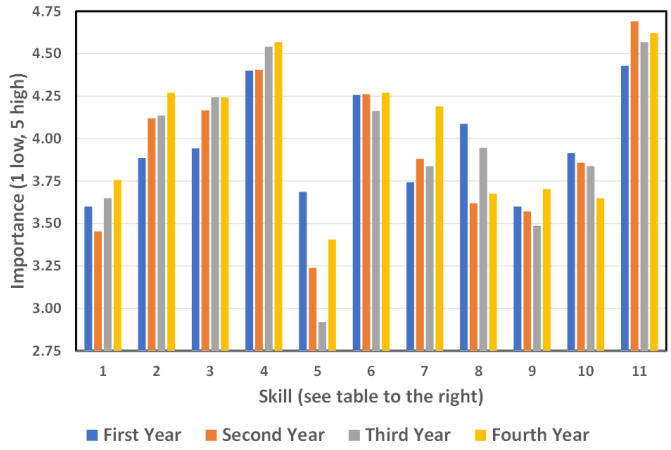


Figure 5: Importance of Technical Skills by Self-Reported Year

Students were asked to evaluate the importance of various non-technical skills via the same Likert scale. Figure 6 shows how students evaluated these non-technical skills. The highest scoring skill was time management, followed by teamwork. It is unsurprising that time management and effective teams are valued by busy engineering students who often work in teams. It is of interest that these skills scored above all other technical skills, indicating that students found them of greater importance, even more than mathematical problem solving.



Number	Skill
1	Write technical reports
2	Communicate effectively in writing
3	Communicate effectively orally
4	Work in teams effectively
5	Manage a project using appropriate project management tools
6	Self-learn and recognize the need for life-long learning
7	Present ideas using appropriate presentation tools
8	Apply the engineering code of ethics
9	Conduct proper literature review
10	Use proper career planning tools
11	Manage your time

Figure 6: Importance of Non-Technical Skills by Self-Reported Year

Four of the non-technical skills are related to communication, all of which trended upward throughout the four-year progression as seen in Figure 7. This indicates that students increasingly view effective communication of all types as a valuable tool in their upper level courses.

Applying the engineering design process (a technical skill) and project management (a non-technical skill) both fluctuated, with higher importance in the freshman and senior years (Figure 8). Researchers again believe this is due to use of these skills in the curriculum. Design projects are used at this institution more in the freshmen and senior years than in the two years in between. The contributions to success that students report reflect the usage of those skills.

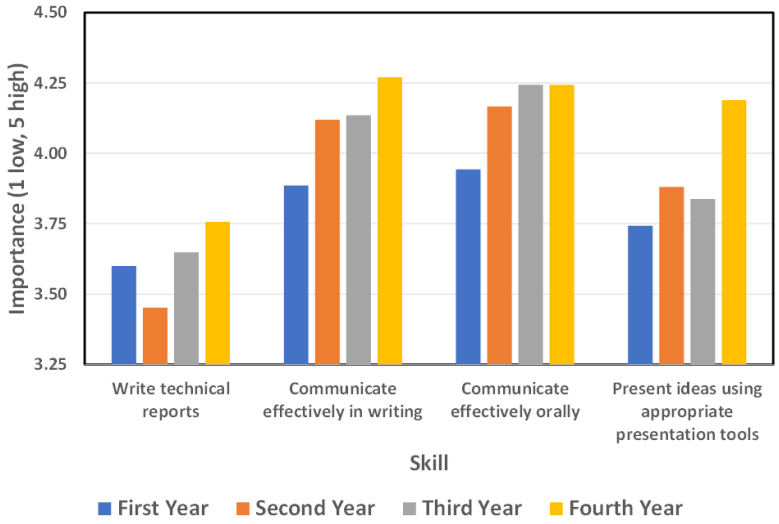


Figure 7: Importance of Communication Skills by Self-Reported Year

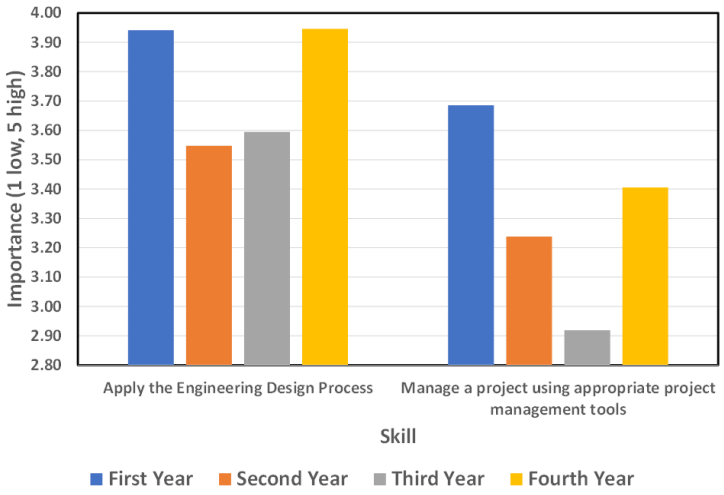


Figure 8: Importance of Design Process Skills by Self-Reported Year

Conclusion and Future Work

This survey was analyzed longitudinally to reflect the importance of various skills that students use as they progress through their curriculum. Time management and teamwork were found to be of greater importance than other skills, including all of the technical skills, throughout all four years. There were upward trends in mathematical problem solving and coding, indicating greater reliance on those skills in later years than in earlier years. Communication skills also trended upward, indicating that students see an increasing importance in effective communication. The application of the engineering design process and project management skills were reported to be of greater importance in the freshman and senior years, where those skills are employed more in the curriculum. This data can be evaluated for factors other than self-reported year. Additional analysis is planned for major, gender, race, and other factors which may influence the perceived importance of these skills and their alignment with ABET accreditation objectives.

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