Full Paper: The Professional and Technical skills that engineering students find most important for success in their major

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Introduction

Technical and non-technical skills are essential to successfully navigate the challenges experienced by engineers in the workplace. In higher education, many technical and non-technical skills are taught in first year courses and are further reinforced in upper-level engineering courses. Examples of soft skills taught in first-year engineering courses include oral communication, presentation skills, teamwork, and project management.

Soft skills are interpersonal skills that support the relationship with other people and complement the technical skills and are essential skills to achieve organizational development and effectiveness. Soft skills can be divided into two categories, functional and adaptive skills[1]. Functional skills are related to tasks and how to solve new problems, and adaptive skills are related to the way in which the engineer conduct themselves and interact with their peers and the environment[1]. Examples of soft skills promoted in engineering courses include written and oral communication, critical thinking, creativity, innovation, emotional intelligence, time management, project management, leadership, and teamwork. Technical skills are specific expertise and knowledge needed to accomplish certain tasks. The technical skills promoted in engineering courses include engineering design process, computer programming, statistical analysis, ethical decision making, estimation, and math problem solving.

Multiple studies have provided information about the importance of non-technical skills in the engineering workplace. For instance, a study by Downing identified a list of soft skills necessary for the success in the workplace[2]. Those skills include problem solving, verbal communication, leadership, and time management [2]. In a study by Parts et al., the investigators identified a list of competencies that helped engineering graduates find a job after their graduation. The most important skills identified in the study were computer skills and learning skills[3].

The purpose of this study is to identify soft and technical skills perceived as important by students enrolled in the different engineering majors. Specifically, this study was guided by the research questions, what technical and non-technical skills are perceived as most important by students enrolled in engineering? and how do the data of those skills differ by engineering major of study? This study is of importance to institutions searching for ways to improve their first year engineering courses and working in identifying technical and non-technical skills that students should master in lower-level engineering courses.

Project Approach

This project was conducted in an R1, land-grant, public institution in the Mid-Atlantic Region. All students enrolled in the Benjamin Statler College of Engineering and Mineral Resources at West Virginia University (WVU) were invited to participate in the study. One-hundred forty-one (141) engineering students completed a survey that was made available via weekly newsletter, flyers, and email. Participants were enrolled in the Aerospace, Biomedical, Chemical, Civil, Computer, and Electrical Engineering Departments. The survey contained likert-scale and open-ended questions. The study was acknowledged by the Institutional Review Board.

Data was analyzed in aggregates based on students' self-reported engineering major of study. For the purpose of this study, only the Likert scale questions were analyzed; the open-ended questions will be analyzed in a future publication.

Results

The primary aim of this study was to explore the significance of various skills, both technical and non-technical, among students in engineering.

Figure 1 summarizes the characteristics of the participants based on the engineering major of study. Most responses originate from Mechanical, Aerospace, Computer, Civil, and Electrical Engineering majoring students (81% of all responses), with Mechanical and Aerospace engineering students having the highest response (33% of all responses). This distribution of responses among engineering majors is comparable to the proportion of students enrolled in the different engineering majors at the institution.

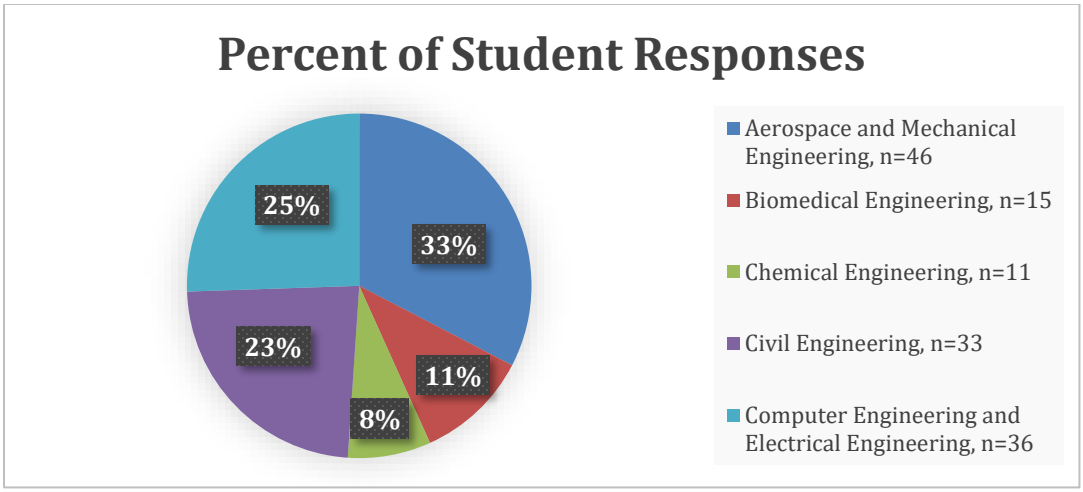

Figure 1. Percent of student responses by engineering major

In terms of technical skills, aerospace and mechanical engineering students highly valued understanding the mathematical language within problems, employing appropriate problem-solving strategies, and proficiency in computational tools and coding. However, data analysis using statistics was least favored among these students, while skills in applying the engineering design process and estimation techniques fell in the middle.

Similarly, biomedical engineering students largely followed this trend, with a slight deviation placing the use of appropriate estimation techniques as the third most valued skill, followed by data analysis using statistics, and then application of the engineering design process. Chemical engineering students' responses aligned closely with those of aerospace and mechanical engineering students.

Conversely, civil engineering students retained the same top-valued skill but ranked the engineering design process second, followed by estimation skills. Data analysis using statistics was deemed the least favored among civil engineering students.

While computer and electrical engineering students' responses generally mirrored those of other departments, there was a notable divergence in the perceived importance of estimation techniques in problem-solving, with students in these departments attributing relatively less significance to this skill.

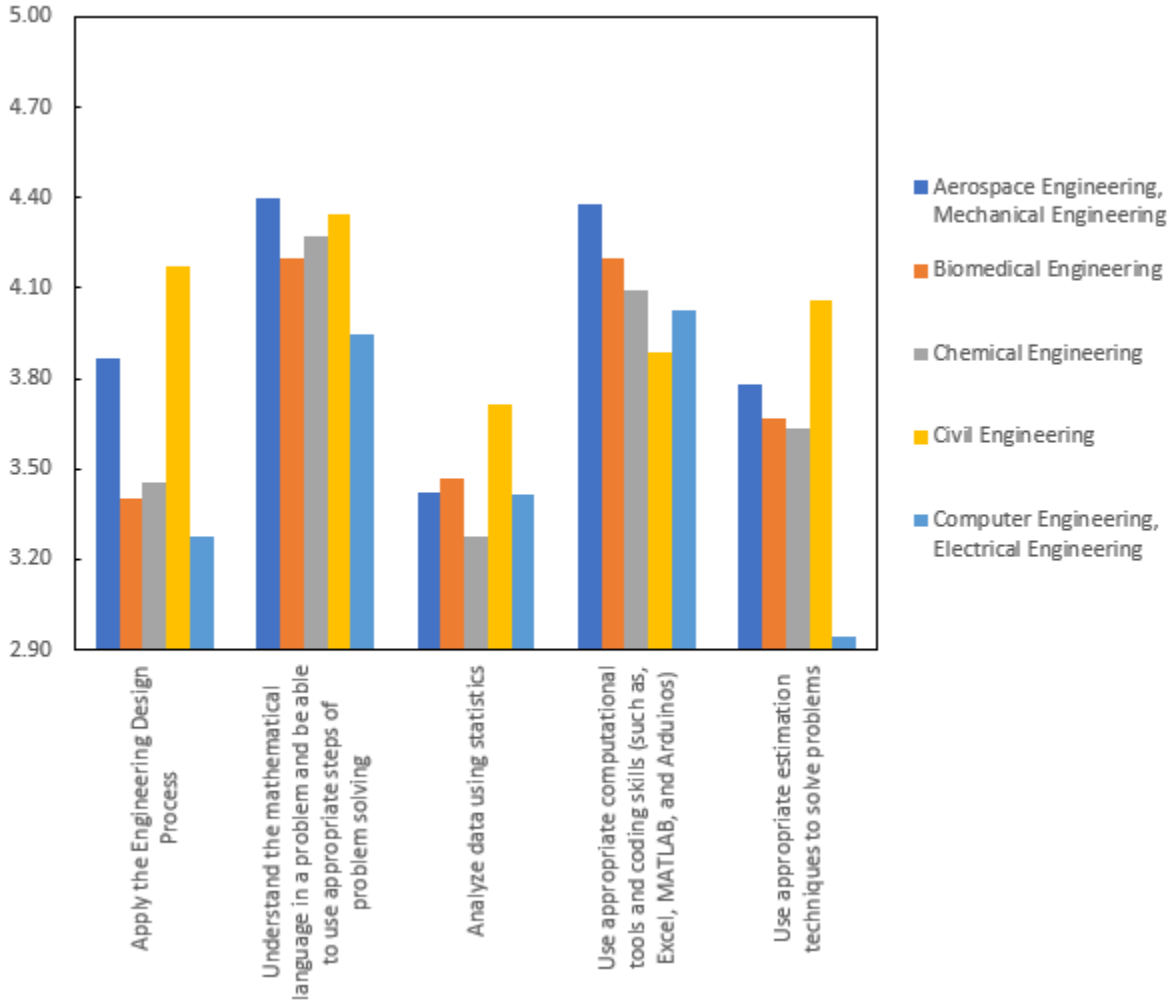

Figure 2. Technical skills versus major

As seen in Figure 3, time management and teamwork emerge as the top non-technical skills valued by students across all departments. Among aerospace and mechanical engineering students, effective time management ranked highest, closely followed by the ability to work collaboratively in teams. Conversely, skills such as proficient written and oral communication, self-directed learning, and recognizing the importance of lifelong learning were consistently ranked second, while project management using appropriate tools was deemed least important.

Biomedical engineering students echoed the trends observed among aerospace and mechanical engineering students, with a slight deviation. Notably, for the chemical engineering students, self-directed learning and recognizing the importance of lifelong learning took precedence over teamwork in the ranking of non-technical skills.

Similarly, civil engineering students' priorities aligned with those of chemical engineering students, placing a high value on effective teamwork and time management. Meanwhile, in the computer and electrical engineering department, managing time and self-directed learning emerged as top priorities.

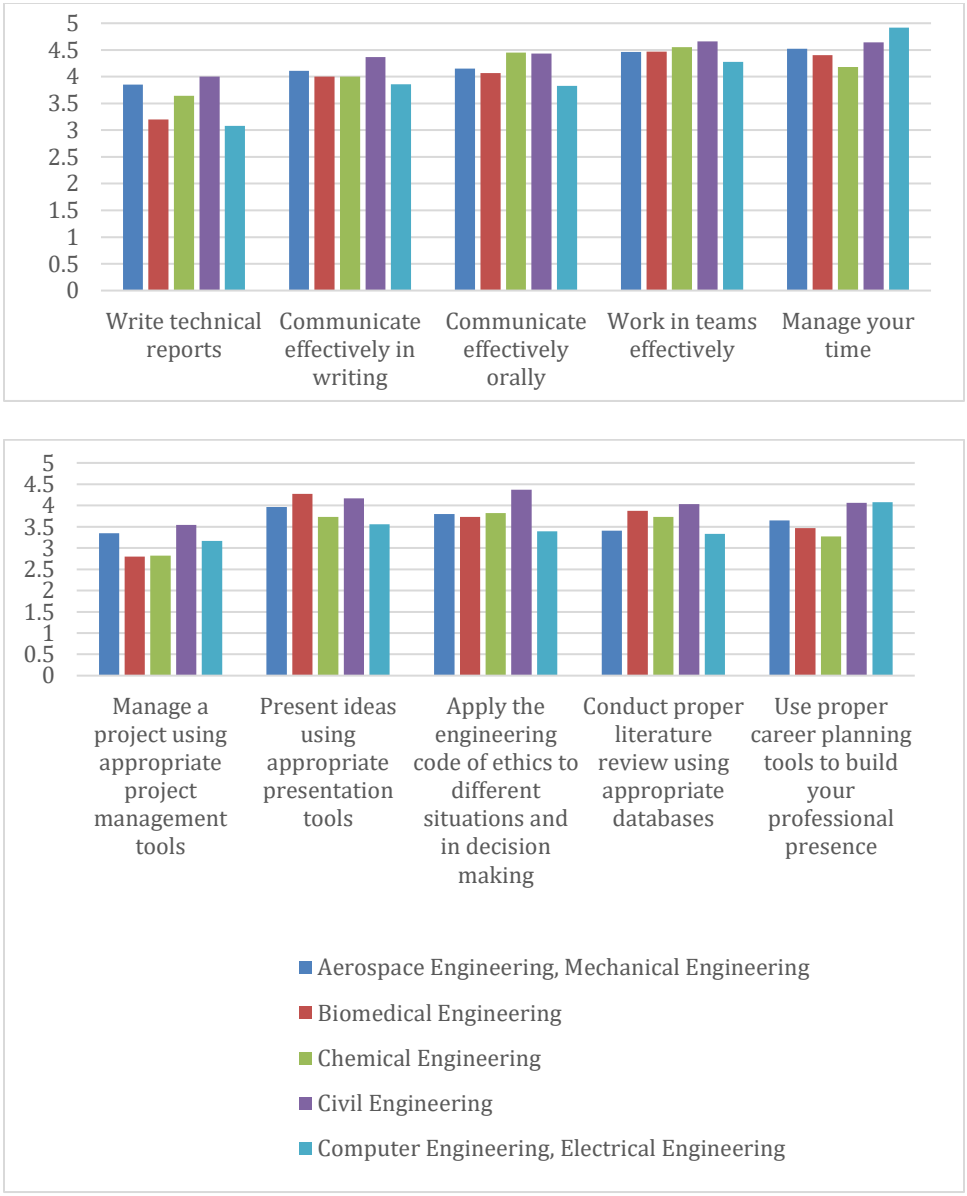

Figure 3. Non-technical skills versus major

Overall, the most valued non-technical skills across all departments were managing time, effective teamwork, and self-directed learning, consistently ranking among the top three choices. Conversely, project management using appropriate tools was consistently among the least valued non-technical skills across mechanical and aerospace, biomedical, chemical, and civil engineering students. Interestingly, it ranked as the second least valued skill among computer and electrical engineering students.

The primary objective of this study was to explore the importance of various skills, including both technical and non-technical skills, among students in engineering and computing sciences. The findings, as depicted in Figures 2 and 3, shed light on some perspectives across different departments regarding the significance attributed to these skills. Figure 2 illustrated the technical skills across all departments; certain technical skills showed unanimous recognition. Understanding the mathematical language within problems, employing effective problem-solving strategies, and possessing proficiency in computational tools and coding emerged as the most highly regarded technical competencies. This consensus underscored the fundamental nature of these skills in engineering and computing education.

The technical skills of understanding the mathematical language in a problem and being able to use appropriate steps of problem-solving were the most valued. In all engineering disciplines, we believed that mathematics served as the language of engineering, providing a framework for expressing and understanding complex concepts and relationships. Engineering students frequently encountered problems that required mathematical analysis and manipulation to devise effective solutions, and this might have been the reason why the students were in favor of this technical skill. Also, the second technical skill liked by most engineering students was the use of appropriate computational and coding skills such as Excel, Matlab, and Arduino. The results in Figure 2 matched with the frequency of technical skills by discipline for bachelor's-level postings found in job posts [4].

Figure 3 provided insights into the perceived importance of non-technical skills across departments. Time management and teamwork emerged as universally valued attributes, reflecting their indispensable roles in professional success. Among aerospace and mechanical engineering students, effective time management took precedence, closely followed by teamwork skills. Conversely, skills such as communication, self-directed learning, and recognizing the importance of lifelong learning consistently ranked second, underscoring their integral role in holistic student development. Biomedical engineering students echoed the trends observed among aerospace and mechanical engineering students, with minor differences. Notably, in the chemical engineering department, a greater emphasis was placed on self-directed learning and recognizing the importance of lifelong learning over teamwork. Civil engineering students' priorities were closely aligned with those of chemical engineering students, emphasizing effective teamwork and time management. Conversely, in the computer and electrical engineering department, managing time and self-directed learning emerged as top priorities, reflecting the unique demands of these disciplines.

Engineering projects in upper-level engineering classes often require collaboration among teams. Effective teamwork ensured that team members could communicate ideas, delegate tasks, and work together efficiently to achieve project goals. Also, teamwork and time management were critical skills in engineering because they facilitated collaboration, improved efficiency, enhanced

problem-solving abilities, fostered innovation, and supported professional development. The results in Figure 3 matched with teamwork and oral and written communication skills that were the most favored non-technical skills found in job posts [5].

Conclusions

To evaluate the content of the first-year engineering curriculum and to support the needs of students enrolled in all engineering majors, the first-year engineering program distributed a survey to all students enrolled in the Benjamin Statler College of Engineering and Mineral Resources. Time management, teamwork, and engineering problem solving were the top skills valued by students in all engineering majors surveyed. Some minor differences were observed in the preference for the engineering design process, with Civil and Mechanical engineering students supporting the need in their curriculum. Statistical analysis and project management were the least selected skills by all students. Based on the data collected, the team is currently restructuring the first-year engineering problem solving course to support the skills perceived as important by students enrolled in the different engineering majors. Feedback from faculty and chairs from the engineering departments is also being used to restructure the course. An in-depth statistical analysis of the data is currently being performed to understand how students' major of choice (data included in this study), and other factors not included in the study (gender, first generation status, year of study) influence the technical and non-technical skills perceived as important by engineering students.

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