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Student Perceptions of Project-Based Learning as Applicable to the Formation of Trusted Professionals

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Forming Trusted Professionals: Student Perceptions of Project-Based Learning

Abstract

Project-based course experiences enhance the student learning atmosphere through the *application* of lesson content and may prove as an advantageous educational technique in developing engineering students into trusted professionals, better prepared to serve the profession immediately after graduation. Applied action in Project-Based Learning (PBL) coursework extends lessons beyond the technical content of the course and creates professional skills development, ideally offering a more holistic training platform for junior engineers. Projects often require students to collaborate with one or more peers, therefore introducing applications of teamwork, leadership, project management, and communications components. Personal development in time management also tends to be introduced in project-based course assignments because of the duration and process of work required to satisfy the comprehensive series of tasks. The opportunity for professional skills development cannot come at the expense of technical skills development. Ideally, not only will the project enhance technical competency, but students completing project-based work should be more capable of solving ill-defined problems and complex problems. Considering project-based learning as an opportunity for the wholesome development of engineering students as trusted professionals, this study collects student perceptions of enhanced learning in professional and technical skills through PBL coursework. Students were surveyed across two distinctly different institutions so comparisons could be drawn between the unique populations. The U.S. West Point Academy was selected to include populations of students seeking professional military careers and supported by curriculum experiences formalizing learning in many professional skills such as teamwork and leadership. The University of Tennessee Knoxville population includes students pursuing civil engineering careers and experiencing fewer structured learning experiences in typical professional skills topics. The data collected shows positive student perceptions towards project-based learning courses which supports this pedagogy as applicable in training trusted professionals. Some variations were observed between the two populations, but general trends showed agreed positive value to professional skills and technical skills development through PBL experiences. This paper includes a brief contextual definition for PBL, a summary of student populations and course structures captured in this study, and a summary of survey responses. Conclusions identifying trends in student perceptions of their learning, competency, and confidence as influenced by PBL are shared and comparisons across the two institutions are discussed.

Keywords

Project-based Learning, Engineering education, ill-defined problems, trusted professionals

Introduction

Project-based learning (PBL) is a continuing educational trend structuring course content to application, and student perception of the experience is important to demonstrating the relevance of the experience. Pedagogical studies have demonstrated improved learning and greater retention of knowledge in application-based lessons, but student awareness and perception of the experiences should be considered as important to the culture developed within a PBL course. While research may support the value, the class atmosphere and presentation of PBL work might be relevant to creating a positive learning experience for students unaware of the practical nature of PBL work or the learning advantage afforded in such assignments. As indicated in student survey responses collected by Fleaher et al. [1], senior undergraduate students had highly positive opinions of PBL's influence on improved professional skills. To further the understanding of student perceptions of project-based learning courses, an extension of the survey to include students in different academic years across two different institutions was sought. The focus of the survey to include both professional skills and technical skills was also modified to expand the collection of student perceptions in PBL courses.

Training the Trusted Professional

Today, civil engineering undergraduate programs support ABET and ASCE initiatives to train junior engineers in both professional and technical skills. Technical skills are developed through coursework to ensure students can perform analysis and design in accordance with standards of the industry to create safe solutions for the built environment. Professional skills such as teamwork and leadership are instrumental in creating successful collaborations on civil engineering design projects. Academic programs are evolving as needed to create junior engineers capable of contributing to the professional world through both the technical and professional aspects of daily service to the industry. In the context of this report, a "trusted professional" is a student trained deliberately in both professional and technical fields of study so they can serve reliably with their peers, supervisors, and the public to support the team dynamics of project design while also competently solving complex engineering design problems.

Background

Engineers have debated the relative importance of professional skills to technical skills for quite some time. A 1993 survey of engineers revealed how design engineers spend their time: 30% problem solving and thinking, 21% communicating their work through documentation, 18% communicating as a consultant, 13% gathering information, 8% planning work, 8% negotiating requirements, and 2% completing other administrative tasks [2]. Surveys in 2004 and 2012 found that design engineers spend approximately 60% of their time engaged in technical work, while the other 40% of their time is spent involved in socially collaborative work [3]. In 2006, a group of civil engineer professionals articulated a global vision for civil engineering [4]. Among the key attributes for the 2025 civil engineer, experts identified the need for engineers to communicate, lead, collaborate with teammates, and manage projects within budget, on time, and within scope. In addition, these experts identified the need for honest engineers with unwavering integrity. More recently in 2019, the American Society of Civil Engineers (ASCE) brought together over 200 engineering educators and professionals to discuss the capabilities needed by today's civil engineers to solve society's complex problems. One of the four major objectives identified as pathways to preparing engineers to meet society's needs was to elevate professional skills to a truly equal footing with technical skills [5]. Specific skills included communication, teamwork and leadership, lifelong learning, professional attitudes, and ethical responsibilities. Thus, while most may agree that technical prowess is the most essential characteristic of an engineer, all should acknowledge the importance of professional competencies to be a successful engineer.

As further evidence, ABET defined engineering as “the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind” [6]. In other words, a critical aspect of engineering is understanding and applying math and science. However, the definition also reveals that the process is just as important as math and science knowledge. Engineers are challenged with leadership, teamwork, communication, creativity to conceive a solution, the ability to design, fabricate, test, and maintain.

The development of these skills is a challenge in a traditional teacher-focused learning environment. On the contrary, PBL, which dates to the 1960s, involves student learning through collaborative teamwork in the pursuit of solving complex problems. In lieu of the customary lecture-style learning model, PBL is a student-centered learning model where students are responsible for their learning and use their creativity, existing knowledge, and intuition to solve complex problems. While there are several active learning models used by faculty (task-based learning, problem-based learning, etc.), the “project” aspect of PBL typically involves the added component of a team communicating their solution through a collaborative report and/or presentation. Studies summarizing the effectiveness of PBL as it pertains to acquiring and applying new knowledge, improving teamwork skills, developing critical thinking/engineering intuition/engineering judgment, and the ability to solve complex problems was recently summarized in the Background Section of a 2021 American Society of Engineering Education paper [1].

While many have written on the advantages and disadvantages of PBL, few have focused on student perceptions of PBL. A relatively recent 2018 study of 104 students at the undergraduate and graduate levels from the United Arab Emirates University completed a questionnaire to assess their views on the effectiveness of PBL [7]. Data analysis involved comparing the mean scores of survey questions querying teamwork, communication skills, technical understanding, self-learning skills, and collaboration. The study revealed undergraduate students perceived PBL in a positive light and attributed PBL to the development of communication skills and teamwork. Graduate students, on the other hand, did not value the collaboration aspect of PBL due to challenges in scheduling meetings. However, graduate students found that PBL did help them improve their self-regulation and self-learning skills and better understand the course material.

A 2020-2021 study of an undergraduate civil engineering program in the United States investigated the effectiveness of PBL during a pandemic [1]. Researchers acquired quantitative and qualitative student feedback in the middle of the COVID-19 outbreak through anonymous authors, Comprehensive Assessment for Team-Member Effectiveness (CATME), and institutional course end surveys. The authors specifically focused on student perception of PBL as it pertained to the following ABET Criterion 3 Student Outcomes [8]:

#1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
#5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
#6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
#7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The authors of this study found that PBL provided a better environment for learning during a pandemic when compared to traditional classroom lectures. The ill-defined nature of solving a problem in lieu of an instructor-guided solution helped improve critical thinking and engineering judgment. The forcing function to work on a team to solve a challenging problem, especially in an environment where social distancing and isolation were the standards, inspired new and creative ways to collaborate and improve communication skills. While the study suggests student support for PBL, the study was limited to one institution and had less than 50 respondents. Some questions from this survey were adopted in the development of this research.

Experimental Method

Collection of student perceptions of project-based learning was performed deliberately to seek input from more than one school population. The selection of two institutions was performed deliberately to identify program and study body distinctions to collect feedback from a wide array of students. The goal of the study was to administer a perceptions survey to a large population of students from different backgrounds and at different stages of their undergraduate careers. While two institutions were selected to improve the diversity of the population, the data was de-identified so perceptions could be combined and discussed universally rather than specifically to a single type of institution. Opportunities to evaluate demographics and influences at institutions are future questions for this work and are not part of this initializing study. A survey was designed based on questions isolating specific types of skills applied in different types of project-based learning courses so initial perceptions could be understood and used to further research questions related to problem-based learning and relevance to developing trusted civil engineering professionals.

Institution Selection

To compare student perceptions of project-based learning across universities, two institutions were selected for examination: The United States Military Academy (USMA) at West Point and The University of Tennessee, Knoxville. The mission of USMA is to educate, train and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country and prepared for a career of professional excellence and service to the Nation as an officer in the United States Army. USMA's dual nature, as both an institution of higher education and a military organization, gives it a unique requirement to develop leaders of character. The civil engineering program at USMA is embedded within the Department of Civil and Mechanical Engineering. The department's mission is to educate, develop, and inspire agile and adaptive leaders of character who design and implement innovative solutions and win in complex environments as trusted Army professionals. Regardless of major, all cadets at USMA take a 24-course core curriculum across the math, science, and humanities disciplines. Additionally, all students take military science and physical education courses during each of their four years. The core curriculum provides a broad foundation for the development of critical and adaptive thinking leaders. The civil engineering majors at USMA take an additional 17 to 18 courses to meet the ABET accreditation requirements. 100% of the students in the civil engineering program take the Fundamentals of Engineering (FE) exam with an 82% average pass rate over the past 5 years. All graduates from the program are commissioned as 2nd Lieutenants in the U.S. Army and will serve a minimum of 5 years in the U.S. Army after graduation.

The University of Tennessee Knoxville is a public land grant university and an R1 research institution. The undergraduate population is just over 23,000 students annually with approximately 3,500 of those students declaring some form of engineering as their major [9]. The Civil and Environmental Engineering department populate approximately 14% of the Tickle College of Engineering and many students seek

employment in the civil engineering professional realm. In 2020, nearly 77% of students completed their undergraduate degree with full-time employment positions already in hand and an additional 16% proceeded to graduate school. While data to confirm sectors of employment are unknown, most are likely to enter engineering or technology fields based on informal classroom and hallway discussions. The department's mission is to encourage thinking to support safer, smarter, and sustainable design solutions for our changing and growing built environment. Professors within the department support these goals through personal research endeavors and in enriching courses with novel and relevant lessons. The curriculum is designed to satisfy ABET accreditation criteria and the program promotes the development of civil engineers prepared to enter the profession. Students from the program are meeting a 78.6% FE exam pass rate (average score from Fall 2017 – Fall 2020), demonstrating one marker for curriculum success in technical skills foundational training.

The selection of these two institutions was performed deliberately to offer an opportunity for student perception comparisons across two unique populations (as summarized in Table 1). Cadets at USMA are engaged in a variety of team building and leadership activities as members of the campus and this may influence perceptions of professional skills as experienced in these non-academic exercises. Students at UTK have opportunities for co-ops and internships which should expose them to communication and teamwork also relevant to their perceptions of PBL courses. Professional paths diverge for these two populations of students as many USMA students will pursue a military assignment directly after graduation while the UTK students will seek work in the civil engineering field immediately upon graduation. These distinctions could influence perceptions and the survey attempts to capture dependent parameters at this broad scale.

TABLE 1: Institution Quick Statistics Comparison

Core Trusted Professional Skills Metrics	**USMA**	**UTK**
FE results	82% (Spring 2017 – Spring 2021)	78.6% (Fall 2017 – Fall 2020)
FE curriculum	Two 75-minute review lessons as part of a 30-lesson 3.-credit hour course taken in the spring semester of senior year. Administered in person with support from faculty.	Single-semester course, 2-credit hours, taken typically in senior year. Administered online and with support from a third-party vendor's online learning program designed for FE preparation.
Professional and Technical training	Students must complete a 24-course core curriculum in addition to physical education and military science courses to complete the Military Academy's professional major. Civil engineering students will also complete all required coursework for their ABET-accredited major. Students are offered summer educational experiences to apply what they have learned in class within a real-world context.	Students are not required but are strongly encouraged to participate in co-ops or internships during their undergraduate experience. College average shows approximately 80% of engineering students participate in one of these professional development activities.

TABLE 1: Institution Quick Statistics Comparison (continued)

Core Trusted Professional Skills Metrics	USMA	UTK
Communication	First Academic Program Goal for the institution and developed/assessed in a myriad of core and major courses. The institutional writing program assesses student writing in Constitutional and Military Law, Officership, Thermal-Fluids, and Civil Engineering Professional Practice and Application.	Single-semester course, 1-credit hour, taken typically in sophomore year. Learning attained through a formal department course.
Leadership	West Point Leader Development System (47-month purposeful integration of individual leader development and leadership development within a culture of character growth). In formal follower roles, students learn honesty, loyalty, dependability, and moral courage. In formal leadership roles, they learn and practice leading peers and organizations.	Informally supported and encouraged through various student organizations such as ASCE, ITE, Hydrolunteers, Chi Epsilon, Tao Beta Pi, and other college-wide engineering structured organizations.
Teamwork	Assessed in some courses to support ABET student outcomes. Throughout the program, this was assessed using CATME. The culminating opportunity for the development and assessment of teamwork lies in a year-long capstone course. As part of the core curriculum, students complete a Human Condition Thread, strengthening their cultural competence and developing their ability to empathize with and value differences in others to build cohesive inclusive teams.	Assessed in some courses to support ABET student outcomes. Primarily encouraged and academically supported in laboratory and senior design courses.

Institutional Review Board

As this work deals directly with student populations, both institutions applied for and were granted a Category Two Institutional Review Board exemption. The stipulations of this exemption require formal participant consent and fully de-identified data. As a result, the survey was administered via an online tool with an integrated consent agreement that had to be acknowledged by the participant before they could begin answering questions.

Design of the Student Perceptions Survey

The survey consists of 19 questions presented in three parts (see below). The questions are largely like those presented in prior work in this area conducted by USMA [1]. Part one covers general biographical

information and group size specifics. Part two contains 13 questions directly related to project-based learning, these questions are multiple-choice and adhere to a Likert scale. Part three has two short answer questions wherein students can elaborate on the perceived advantages and disadvantages of project-based learning. The questions are aligned to many, but not all types of professional or technical skills. To maintain a relatively short survey design, professional topics such as diversity, inclusion, ethics were not included. Technical skills such as economics, risk, uncertainty, and data analysis were also unrepresented in this short survey.

A review of the previous survey was performed deliberately to align the questions to specific hypotheses questioning the value of PBL work as supporting the development of trusted engineers. These hypotheses are summarized as: (1) Students will perceive improved technical skills through course design projects and (2) Students will recognize improved professional skills through course design projects.

Part 1: Biographical Questions

1. Have you had an internship or co-op?
2. The following answers are based on the work in which course?
3. What grade do you anticipate earning in the above course?
4. How many members were in your project group?

Part 2: Project-based Learning Perceptions

Technical Skills-Focused

1. The course project has increased my confidence in my technical competency.
2. The course project increased my technical competency.
3. The course project has increased my confidence in performing engineering design work.
4. The course project has increased my confidence in performing engineering analysis.
5. This course project has increased my ability to perform technical engineering work.
6. The course project has increased my ability to think critically about a problem.

Professional Skills-Focused

7. The course project has increased the amount of trust I have in my own ideas, assumptions, and/or solutions.
8. The course project has increased my motivation to learn about new subjects or topics.
9. The course project has increased my desire to seek out new knowledge on my own that is relevant to my studies.
10. The course project has increased my resourcefulness in finding useful information to solve engineering problems.
11. The course project has improved my ability to cooperate outside of traditional classroom learning.
12. The course project has increased my professional communication/presentation skills.
13. The course project has increased my group communication/collaboration skills.

Part 3: Open Response Project-based Learning Feedback

1. Do you feel that project-based learning has any ADVANTAGES over traditional classroom learning?
2. Do you feel that project-based learning has any DISADVANTAGES compared to traditional classroom learning?

This survey was administered to 25 (USMA) students and approximately 200 (UTK) students (Tables 2 and 3). All students were in their Junior or Senior year. The survey was deployed prior to final grades in the subject semester and then again within the first month of the subsequent semester. The request to participate was presented to the students no more than four times total. All students agreed to a standard consent form prior to completing the survey, no signature was required. The subject group of students was pulled from a variety of classes all of which utilize a project-centered curriculum. Each course represented integrates the course project in a different style and the course grade, course lessons, and professor emphasis on the technical and professional skills vary.

At USMA CE493/494 is a year-long capstone design course. The course is a 3.0 credit hour course with all in class hours as capstone design time and no formal lecture hours occur. The capstone teams consist of 3-6 students. Each capstone team has a different capstone design project. With no formal lecture lessons in the course, students are expected to complete the engineering design process and develop the design solution for each capstone design project using knowledge previously learned in engineering coursework and with capstone advisor input. In addition to the capstone design solutions, students are also formally evaluated on oral and written technical and non-technical communication through presentations to various audiences and submitted reports and publications.

The variety of students surveyed at UTK include junior and senior students who participated in either an undergraduate design course, laboratory courses with design project work, or the capstone course. These courses offered project experiences with a variety of team sizes ranging from 1-7 with some laboratory courses including single-person design tasks while the senior design course often has team sizes with 4-6 students. The senior design course at UTK is a one-year project summing to a total of (4) credit hours and a majority of class session hours are dedicated to professional skills development focused primarily on project management, time management, and communication. The laboratory and junior-level design course differ and do not include formal lessons in professional skills. The program offers a technical communications course and other skills, such as leadership and teamwork, are expected to be supported by non-mandatory extra-curricular activities offered informally at the institution. In all courses included within the report, components of graded work do assess professional skills such as communication because the students are expected to be competent in these skills upon entering these courses.

TABLE 2: Survey Population USMA

Course number	Course title	Number of students invited to survey	Project grade as % of course grade	Professional Skills	Technical Skills
CE493/494	**Civil Engineering Capstone Design**	25	100	40%	60%

TABLE 3: Survey Population UTK

Course number	Course title	Number of students invited to survey	Project grade as % of course grade	Professional Skills	Technical Skills
CE 400	**Civil Engineering Capstone Design Semester II**	14(F21) 49(S22)	70	30%	70%
CE 399s	**Civil Engineering Capstone Design Semester I**	20(S22) 49(S22)	35	65%	35%
CE 463	**Structural Behavior Measurements Laboratory**	44	20	0%	100%
CE 371	**Structural Eng. Introduction**	40	40	50%	50%

Analysis and Discussion

Student perceptions were sought to satisfy two over-arching hypotheses: students perceive PBL experiences as valuable to professional skills development and students perceive PBL experiences as valuable to technical skills development. Broadly, results from the survey show students felt professional skills such as communication and teamwork increased due to course projects, showing a positive perception towards professional skill development. Comparable trends in the survey responses show many students perceived improved abilities in critical thinking and technical abilities. The pairing of positive perceptions in technical skills and professional skills development supports PBL experiences as relevant in developing trusted engineering professionals. Interestingly, the correlation between positive perceptions of PBL courses and professional experiences such as internships or co-ops could not be confirmed within the data collected. Comparisons in agreement showed students with internship experience or without internship experience trended in the same agreements, indicating the internship experience or lack of experience did not influence their perception of the value of PBL courses. The data did show a minor trend indicating students with internship experience were less likely to disagree with increases in skills development in PBL courses whereas more students without internship experience did respond with disagreeing sentiments towards PBL courses as valuable to their training. Open-ended prompts offered in Part 3 of the survey were available to the students, but response rates were minimal and therefore not included in analysis of the responses.

Professional & Technical Skills Development

The survey requested perceptions related to technical skills development across five prompts and overall perception from all respondents from both institutions showed students agreed project-based learning experiences enhanced the development of their technical skills (Figure 1). Overwhelmingly, confidence in analysis work and technical engineering work was shown as most significantly agreed with students highly confident in the project to increase their abilities. The most influential skill, perceived by the students, as indicated in the survey responses was reported as "…increased resourcefulness…" which is likely due to the open-ended complex design problem students face in PBL course projects. Perceptions in professional skills development varied based on the specific professional skill. The ability to trust their

ideas, seek new knowledge, and motivation to learn about new subjects all showed students agreed the project supported skills training, but with only approximately 30% of respondents strongly agreeing. Over 80% of respondents, however, agreed the project improved their resourcefulness in finding information and in their technical communication skills. The need to solve problems they have not faced before and the structure of most courses to award graded credit towards presentations and other forms of communication likely influence these perceptions which is an appropriate and anticipated outcome.

FIGURE 1: Part 2 Survey Responses (neutral axis denoted with red line)

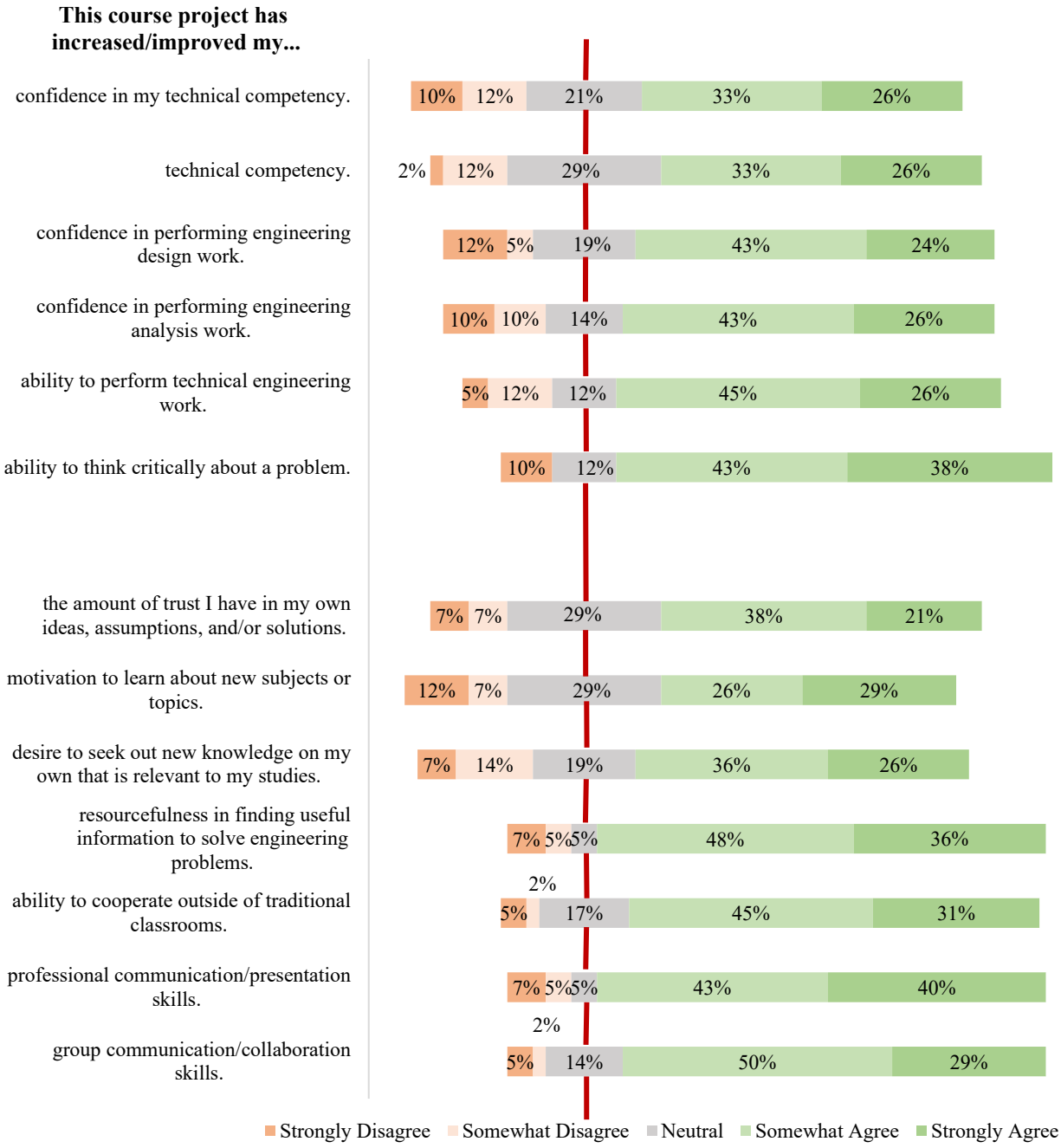

FIGURE 2: Perception Responses by Institution, where Line A Represents UTK and Line B Represents USMA (neutral axis denoted with red line)

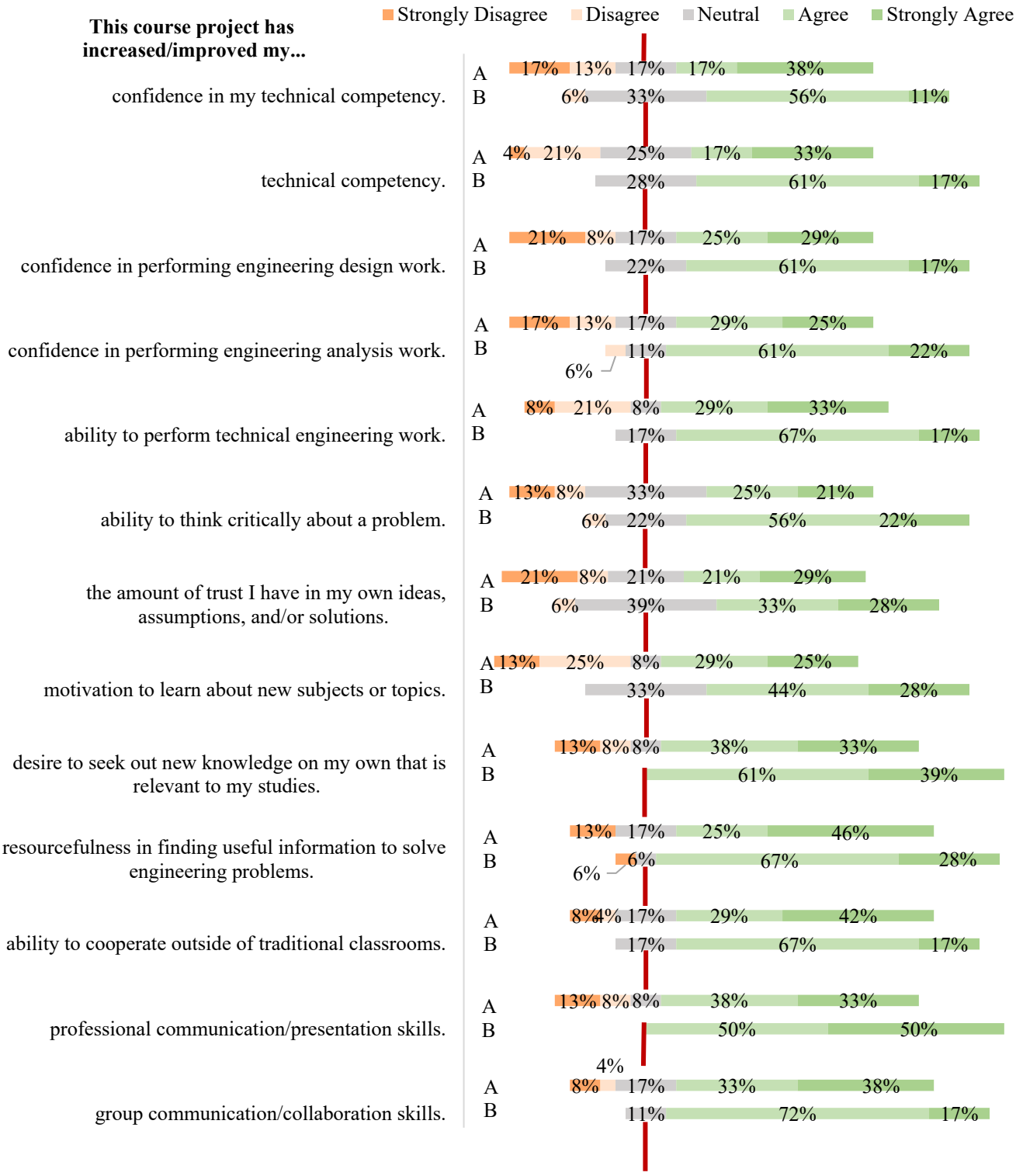

TABLE 4: Some Notable Comparisons Between Institutions

Survey Prompt	USMA Responses		UTK Responses	
	Strongly Agree	Strongly Agree and Agree	Strongly Agree	Strongly Agree and Agree
…inc. communication/presentation…	50%	**100%**	33%	**71%**
…increased resourcefulness…	39%	**100%**	33%	**71%**
…trust my ideas…	22%	**78%**	21%	**46%**
…inc. confidence…analysis work…	28%	**89%**	25%	**54%**
…inc. confidence…design work…	17%	**83%**	29%	**54%**
…inc. confidence…tech. competency…	**11%**	67%	**38%**	54%

Perceptions Across Institutions

The variability of perceptions and the alignment between technical and professional skills were uniquely different between the two populations of students. As shown in Figure 2, the variability on the Likert spectrum is visible and students at UTK showed a much more varied perception of project-based learning. USMA students showed a recognizably higher overall agreed opinion of project-based learning as valuable or influential in skills development with no fewer than 60% "agree" rates across all questions in the survey and an average score of 82% 'agree' across the entire list of survey questions. Students from UTK showed "agreement" rates less than 60% more often across the suite of questions and the average agreement was significantly lower than USMA's responses. As described in Table 1, some distinction between the responses in professional skills across the institutions may be influenced by the more formal teamwork and leadership training offered to the USMA students. These students may be experiencing more applied opportunities to see the value of these types of professional skills due to their academic training and some career training specific to their institution. While UTK students had a much more varied perception of project-based learning, the strong agreement with project-based learning as improving abilities in technical skills was comparable and greater in eight prompts than the USMA students. Average differences in 'total agreement' (strongly agree and agree) differed between the institutions by 13-35 percentage points and only three responses found 'agree' results less than 6 percentage points different. It is worth noting here the diversity between the populations of students at the two institutions. At USMA, more than 99% of students will serve as commissioned officer in the US Army following graduation. These graduates are unlikely to serve in a traditional engineering capacity within the first 6-8 years following graduation. Whereas, at UTK graduates of the CE program are much more likely to find themselves in civil engineering careers upon graduation. The likelihood of civil engineering careers immediately following graduation for UTK students and the commonality of an Army career for USMA students is a possible contributor to the variation in student perceptions of PBL especially as noted between the technical skills and professional skills prompts.

Conclusion and Further Research

Hypotheses pursued within this work reached supporting conclusions to show project-based learning is perceived to improve technical and professional skills, ultimately supporting PBL experiences as useful in developing trusted engineer professionals. Results were not conclusive in supporting the hypothesis that co-op or internship experience would influence this opinion. Differences across the two populations of students were recognized, but not significantly different. Preliminary data analysis was unable to show

strong correlations or divergence in the two populations, but a review of the gross responses does indicate more extensive surveying across multiple academic years is warranted as the data at the time of release for this publication is considered sparse. The work offered within this study demonstrates student perceptions are unique and may not be as definitive as studies supporting PBL as a valuable learning pedagogy. While the science of teaching and learning is critical to defining PBL as a valid method for education, student perceptions need to agree for the method to be applicable in the field of civil engineering and for training trusted professionals entering the civil engineering profession. Extended hypotheses to be studied might include a closer evaluation of the demographic differences across the two populations and a more detailed course comparison. Ultimately, the survey responses collected by these 225 students indicate young engineers perceive PBL experiences as positively influencing their development of both technical and professional skills and PBL coursework should be viewed as an opportunity to train trusted engineer professionals.

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