The Influence of Self-Efficacy on Performance in different Electrical Engineering Learning Environments

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Students' Engineering Self-Efficacy Influences from Different Electrical Engineering Course Learning Environments: A Work in Progress

Abstract

This work-in-progress study investigates how self-efficacy influences electrical engineering students' performance and motivation across two different learning environments: a traditional lecture-based course, Signals and Systems, and a project-based, hands-on course, Computer Tools Lab. Understanding how confidence develops across these different instructional contexts may help improve student learning and persistence in the major. The study is part of a curricular reform initiative at the University of South Florida focused on student-centered education.

This study represents a focused component of a broader NSF RED initiative aimed at transforming engineering education. Specifically, the Signals and Systems course represent a lecture-based, mathematically intensive learning environment, while the Computer Tools Lab represents a project-based, hands-on learning environment emphasizing computational modeling, and programming. This student-led project has the inherent goal of expanding reform initiatives that promote undergraduate student inquiry about their own learning experiences and preparation for future engineering work.

The study used a mixed-methods design. Twenty students completed a survey measuring confidence in analytical problem solving, programming, computational modeling, and engineering design. Semi-structured interviews with three participants gave insight into how course experiences, feedback, and challenges shaped their confidence. Quantitative data was described and analyzed using repeated-measures ANOVA; qualitative responses were coded thematically using Bandura's four sources of self-efficacy.

Early survey and interview responses suggest that students experience different types of mastery opportunities in each course. However, students' perceived ability to succeed appeared to be shaped not only by instructional style but also by the learning tools available outside of class, including tutoring, online resources, studying with peers, past exams, and homework practice. The project-based environment appeared to support confidence through hands-on experimentation and visible progress, while the lecture-based environment presented challenges that may strengthen analytical reasoning but sometimes lower perceived confidence during difficult topics.

Introduction

The demand for electrical engineers in the United States continues to grow as technological innovation accelerates. The U.S. Bureau of Labor Statistics estimates that employment in electrical and electronics engineering will rise by approximately 7% by 2034, with more than 17,500 job openings projected each year [1]. Success in this field may depend as much on a student's belief in their own ability as on their mastery of equations or hands-on engineering skills. Among the social–emotional competencies shaping academic outcomes, self-efficacy emerges as a critical determinant of student motivation and persistence in engineering programs.

As engineering curricula evolve, important questions arise about how different instructional formats shape students' beliefs in their engineering abilities. Self-efficacy, defined by Bandura as an individual's belief in their capacity to perform actions necessary to achieve specific goals [2], [3], has been linked to performance and long-term engagement in STEM fields. Yet limited research has examined whether traditional lecture-based courses or project-based courses foster self-efficacy through different mechanisms. Understanding these differences is important for curriculum redesign efforts.

Within this context, the study aims to examine how self-efficacy develops among electrical engineering students enrolled in two contrasting learning environments: Signals and Systems, a math-intensive, lecture-driven course, and Computer Tools Lab, a project-based course emphasizing computational modeling and hands-on experimentation.

Literature Review

Self-efficacy is a central predictor of motivation, persistence, and performance in academic environments [2], [3]. In engineering education, where students frequently encounter complex tasks and unfamiliar design challenges, self-efficacy plays a crucial role in shaping how students approach and interpret difficulty. Students with higher engineering self-efficacy demonstrate stronger resilience, improved problem-solving strategies, and a greater likelihood of persisting in engineering programs [6], [7]. Research has consistently shown that self-efficacy is not merely a byproduct of ability but is shaped by learning environments, feedback, and opportunities for meaningful engagement with engineering tasks [4], [5].

Within engineering programs, self-efficacy has been examined across design-oriented environments, analytical coursework, and early engineering identity formation. Carberry et al. found that iterative design tasks, where students repeatedly refine solutions, significantly enhance design self-efficacy [5]. Mamaril et al. validated distinct but interrelated dimensions of engineering self-efficacy, highlighting the importance of understanding how different course structures support these facets [7]. Collectively, these findings underscore the importance of examining how specific instructional environments influence students' beliefs about their engineering capabilities. Bandura identifies four primary sources of self-efficacy: mastery experiences, vicarious learning, verbal persuasion, and emotional or physiological states [3]. In engineering contexts, mastery experiences are the most influential predictors of students' confidence [8]. Laboratory courses, coding activities, and hands-on design work often provide rich opportunities for mastery.

Vicarious learning, or confidence gained by observing peers succeed, also contributes significantly to engineering students' self-belief, particularly in collaborative problem-solving contexts [9]. Verbal persuasion, including instructor feedback and encouragement, has been shown to shape students' persistence during difficult tasks and influence academic decision-making [10]. Finally, emotional states play an important role: anxiety, stress, or cognitive overload can decrease perceived competence, particularly in mathematically intensive engineering courses [11].

Taken together, these sources highlight the deep connection between classroom structure and the formation of engineering self-efficacy, reinforcing the need for research that examines how instructional formats support or hinder student confidence. Engineering programs typically blend theoretical, lecture-based instruction with laboratory or project-based coursework, each of which influences student learning. Lecture-based courses emphasize mathematical modeling, conceptual abstraction, and structured problem solving. Although these environments develop essential analytical skills, they may also challenge students' confidence if the connection between theory and application is unclear or if students lack opportunities for repeated mastery [12], [13]. Research shows that lecture-dominant environments can contribute to reduced confidence among some engineering students, especially when assessments are high-stakes and professors provide little to no feedback[12].

In contrast, project-based learning (PBL) environments offer more frequent mastery experiences and opportunities for collaboration. Studies consistently show that PBL enhances engineering students' self-efficacy by providing authentic problem-solving experiences and visible indicators of progress [14]-[16]. Hands-on computational and programming environments function similarly: iterative debugging, experimentation, and peer collaboration have been shown to increase students' confidence in their technical abilities [17], [18].

Despite the strengths of each environment, little research directly compares how lecture-based and project-based courses support self-efficacy within the same engineering curriculum. This gap is particularly relevant for programs wanting to undergo redesign efforts.

Methodology

This study employed a mixed-methods research design to investigate how electrical engineering students' self-efficacy develops within two contrasting learning environments. A mixed-methods approach was chosen to capture both quantitative trends in students' perceived confidence and qualitative insights into how course experiences shape those perceptions. This design aligns with engineering education research that combines quantitative and qualitative data to better understand student learning and development [19], [20]. Ethical approval was obtained from the University of South Florida Institutional Review Board for the broader student-led research program, and this specific study was determined by the university's review board to be a quality improvement project.

Participants were recruited from students enrolled in both courses during the Fall 2025 semester. Recruitment messages were distributed through instructor announcements and course communication channels. Participation was voluntary, and all students aged 18 or older were eligible to participate. Twenty survey responses (n = 20) were included in the quantitative analysis. From this pool, a subset of three volunteers participated in follow-up interviews to provide insight into their experience. This sampling strategy reflects a typical convenience-plusvolunteer model commonly used in engineering education studies and is appropriate for research examining classroom-level phenomena [7], [19].

Research Design

The self-efficacy survey was adapted from previously validated instruments developed by Mamaril et al. [7] and Carberry et al. [5]. Items were selected and modified to reflect the types of analytical, computational, and design tasks students encountered in each course. This approach allowed the survey to remain grounded in established measures of engineering self-efficacy while better aligning with the specific course contexts examined in this study. The first phase of the study involved administering a self-efficacy survey consisting of three subscales: analytical engineering self-efficacy, computational and programming self-efficacy, and general engineering or design self-efficacy. Items were measured on an 11-point Likert scale ranging from "0" to "100." The survey required approximately 10–20 minutes to complete. Survey responses were analyzed using descriptive statistics to examine mean self-efficacy scores for each course, differences across the three self-efficacy subdomains, and distribution patterns indicating varying confidence levels. Because the same participants responded to each self-efficacy domain, repeated-measures analysis of variance was also used to compare differences across domains.

To complement the survey data, semi-structured interviews were conducted with a subgroup of participants representing both course environments. Interview questions were designed to explore students' experiences with coursework, instructional structure, feedback, collaboration, mastery opportunities, learning resources, and emotional responses to challenges. The interview protocol was grounded in Bandura's four sources of self-efficacy, including mastery experiences, vicarious learning, verbal persuasion, and emotional states [2], [3].

Interviews lasted approximately 10–15 minutes and were conducted in person. All interviews were audio-recorded and transcribed for analysis. All participants were provided with consent forms in accordance with the University of South Florida's approved consent procedures prior to participating in the survey or interviews. Participation was voluntary, and students could withdraw at any time without penalty. No identifying information was associated with the final data set, and all data was stored securely during and after the study.

Findings

Table I

Summary of Self-Efficacy Scores by Domain

Self-Efficacy Domain	**Mean**	**Standard Deviation**	**% ≥ 70**	**% ≤ 50**
General Engineering	70.0	14.2	60%	5%
Analytical (Signals & Systems)	67.4	20.0	55%	25%
Computational (Computer Tools Lab)	65.6	20.6	50%	20%

This study examined patterns of self-efficacy among undergraduate electrical engineering students using survey data collected from 20 responses (n = 20). Across all respondents, general engineering self-efficacy was the strongest domain (M = 70.0, SD = 14.2), followed by analytical self-efficacy associated with Signals and Systems (M = 67.4, SD = 20.0) and computational self-efficacy associated with Computer Tools Lab (M = 65.6, SD = 20.6). These results suggest that students generally viewed themselves as capable future engineers, while confidence in specific technical domains varied.

To further examine differences in self-efficacy across domains, a repeated-measures analysis of variance (ANOVA) was conducted because the same participants responded to each self-efficacy domain. Results indicated that differences across general engineering, analytical, and computational self-efficacy were not statistically significant, $F(2, 38) = 0.48$, $p = 0.625$. A course-focused comparison between analytical self-efficacy in Signals and Systems and computational self-efficacy in Computer Tools Lab also showed no statistically significant difference, $F(1, 19) = 0.17$, $p = 0.684$. These results suggest that differences in average self-efficacy scores should be interpreted cautiously. However, the relatively large standard deviations in the analytical and computational domains indicate substantial variability in student confidence, which may reflect differences in prior experience, academic preparation, and how individual students respond to different learning environments.

Qualitative Interview Findings

To provide additional context for the survey results, qualitative interview responses were analyzed to identify how students described the factors that shaped their confidence in each course environment. Across the interviews, students emphasized that their ability to succeed was not determined only by an instructor's teaching style, but also by the support systems and learning tools available outside of class. Participants described tutoring, online resources, studying with friends, reviewing past exams, and practicing homework problems as important contributors to their confidence and performance. One recurring theme was that self-efficacy developed when students had access to multiple ways of working through difficult material, rather than relying on lecture alone. This theme was especially relevant in Signals and Systems, where students described the course as conceptually difficult and exam-driven. In contrast, students in Computer Tools Lab more often described confidence as developing through direct experimentation, debugging, and visible progress during assignments. These findings suggest that course structure mattered, but students' perceived ability to succeed was also shaped by the broader ecosystem surrounding the course.

Students' analytical self-efficacy, associated with Signals and Systems, reflected moderate confidence. Many students reported confidence in working with equations and problem sets, viewing success in their coursework as evidence of their engineering capability. However, a subset of students expressed lower confidence in analytical problem solving. Open-ended responses indicated that the abstract nature of the course material and reliance on exams contributed to uncertainty. Several students reported that they were unsure of their level of understanding until exam results were returned, which limited opportunities for feedback and contributed to anxiety. These findings suggest that while rigor can reinforce confidence for some students, it may undermine self-efficacy for others when mastery is difficult to assess during the learning process.

Computational self-efficacy, associated with Computer Tools Lab, also demonstrated moderate confidence with substantial individual variation. Many students reported increased confidence in using programming tools, building simulations, and debugging code. Survey responses indicated that repeated practice and hands-on assignments helped students develop confidence through visible progress. Qualitative responses highlighted that coding often normalized mistakes and supported learning through trial and error. At the same time, some students reported continued difficulty with unfamiliar tools or complex debugging tasks, indicating that computational confidence, while supported by hands-on practice, was not uniformly strong across all participants.

General engineering self-efficacy was consistently higher than class-specific self-efficacy. Students across both courses expressed confidence in their long-term ability to succeed as engineers, though the basis for this confidence differed by learning environment. This distinction suggests that general engineering confidence can be supported through both analytical challenge and applied experience, even when students feel less confident in specific skill areas. Qualitative responses revealed that collaboration and emotional experiences played important roles in shaping self-efficacy. Students in Computer Tools Lab frequently described peer interaction as beneficial, particularly during debugging and problem-solving sessions. Observing peers encounter similar challenges helped normalize difficulty and build confidence.

In contrast, students in Signals and Systems more often described learning independently. Although some students participated in informal study groups, the course structure did not consistently promote collaboration, which led some students to question their abilities when struggling independently. Emotional responses also differed by course. Students in Signals and Systems commonly associated stress with exam performance and fear of failure, whereas students in Computer Tools Lab described stress as a temporary and productive part of the learning process that often preceded successful outcomes.

Discussion and Conclusion

This study's findings align with Bandura's social cognitive theory, particularly the role of mastery experiences, vicarious learning, and emotional states in shaping self-efficacy [2], [3]. Although statistical differences across self-efficacy domains were not significant, the descriptive trends and qualitative responses suggest that students may experience confidence-building opportunities differently across learning environments.

Together, these results suggest that self-efficacy development was shaped not only by instructional format but also by the availability of external learning supports, peer collaboration, feedback opportunities, and repeated practice. The large standard deviations in analytical and computational self-efficacy further suggest that course environments may not affect all students in the same way. Some students may gain confidence from rigorous analytical challenges, while others may benefit more from hands-on experimentation, peer interaction, and frequent opportunities to test their understanding.

These findings have implications for electrical engineering course design. Lecture-based courses such as Signals and Systems may better support self-efficacy when students are provided with more frequent formative feedback, structured problem-solving practice, and opportunities for collaboration. Similarly, project-based courses such as Computer Tools Lab may support confidence by maintaining visible progress and normalizing trial-and-error learning. Rather than treating lecture-based and project-based environments as competing models, engineering programs may benefit from intentionally combining analytical rigor with applied learning and accessible support structures.

While this study offers meaningful insights, several limitations should be acknowledged. The relatively small sample size ($n = 20$) limits the generalizability of the findings, and the small number of interview participants ($n = 3$) may not fully capture the range of student experiences. Additionally, the use of self-reported survey data introduces potential bias in how students perceive and report their confidence. As a work-in-progress study, these findings should be interpreted as preliminary. Future research will expand the sample across multiple semesters, deepen qualitative data collection, and incorporate longitudinal measures of self-efficacy to strengthen the robustness of the conclusions.

In conclusion, this study highlights the importance of instructional design and learning support systems in shaping engineering students’ self-efficacy. By combining analytical rigor, collaborative learning, hands-on practice, and accessible academic support, engineering programs may better support student persistence in engineering disciplines.

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