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Building Better Electrical and Computer Engineering Graduates: A Scaffolding Approach to Active, Inclusive, and Project-Based Learning

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1. Introduction

This Work-in-Progress study investigates the integration of project scaffolding (e.g., a structured approach that breaks projects into smaller, manageable phases) into undergraduate electronic and computer engineering courses in programming, signal processing, and numerical analysis. Project-based learning offers powerful opportunities for engineering students to apply knowledge, but large, complex assignments can often feel overwhelming and limit student engagement.

The scaffolds include a project proposal, progress update, and final submission, each designed to incrementally reinforce learning and problem-solving skills. A quantitative approach is used to assess impact: quantitative data are collected through retrospective post-then-pre surveys, course surveys, and cross-course comparisons, while qualitative data are gathered from student reflections. The guiding research question is as follows: *How does integrating scaffolding improve student perceptions of learning and engagement in undergraduate Electronic Engineering courses?*

2. Background

2.1 Scaffolding Approach

Scaffolding, from a pedagogical standpoint, refers to the intentional structuring of learning experiences in which instructional support is gradually introduced, adjusted, and eventually withdrawn as students develop greater competence and independence [1]. Rooted in constructivist learning theory and Vygotsky's concept of the zone of proximal development [2], scaffolding helps learners bridge the gap between what they can do independently and what they can achieve with guidance.

In engineering education, scaffolding supports deeper conceptual understanding, improves self-regulation, and promotes equitable learning by making expectations explicit and breaking complex tasks into manageable components [3]. A common and effective three-step scaffolding approach in project-based learning consists of a project proposal, a progress update, and a final submission [4]. The project proposal phase encourages early engagement, problem framing, and feasibility analysis while allowing instructors to provide formative feedback and course correction. The progress update serves as a mid-course checkpoint that reinforces accountability, supports iterative design, and helps identify misconceptions or technical challenges before they become entrenched. The final submission emphasizes synthesis, reflection, and professional communication.

While scaffolding offers clear benefits, including improved learning outcomes and reduced student anxiety, it also presents challenges such as increased instructor workload, the need for careful alignment with learning objectives, and the risk of over-scaffolding, which can limit student autonomy if supports are not gradually faded [5].

2.2 Scaffolding Approach in Electrical and Computer Engineering Education

In electrical and computer engineering (ECE) education, scaffolding has been widely applied across laboratories, design courses, and capstone experiences to support active, inclusive, and project-based learning [3].

For example, in introductory circuits and electronics courses, scaffolded lab sequences often guide students from highly structured experiments toward open-ended design challenges, enabling novices to build confidence while developing analytical and troubleshooting skills [6]. In embedded systems and computer engineering courses, scaffolded programming assignments frequently progress from template-based code and guided milestones to fully independent system integration projects [7]. Capstone design courses in ECE commonly employ scaffolded project management structures—such as staged proposals, design reviews, and interim demonstrations—to mirror professional engineering practice while supporting diverse student teams [8].

Research has shown that these scaffolded approaches improve retention, particularly for underrepresented students [9], by reducing cognitive overload and making complex engineering practices more accessible. Collectively, these applications demonstrate how scaffolding can be strategically embedded within ECE curricula to enhance technical mastery, teamwork, and inclusive participation without sacrificing rigor or authenticity.

3. Methods

3.1 Study Design

The new curriculum intervention implemented a scaffolded project-based framework across three undergraduate courses: Programming, Signal Processing, and Numerical Analysis and Scientific Computation. The courses included students enrolled in Electronic Engineering program, as well as the Applied Mathematics and Computer Science program. A total of 41 students participated in the study. The goal was to enhance student engagement, confidence, and autonomous learning by breaking down a semester-long project into three structured phases:

1. Project Proposal: Students identified an engineering problem aligned with course concepts, outlined objectives, and proposed methods or tools for analysis.
2. Project Update: Mid-semester progress reports and instructor feedback sessions emphasized technical refinement, teamwork, and communication.
3. Final Project Submission: Students delivered a comprehensive report, supporting code or simulations, and a final presentation demonstrating integration of learning outcomes.

Each stage included clear rubrics, feedback checkpoints, and opportunities for peer collaboration through lab discussions and code reviews. Reflective prompts guided students to self-assess their learning progress and problem-solving strategies. Data were collected post-course via retrospective post-then-pre surveys to assess the intervention's impact on confidence, engagement, and collaborative learning behaviors.

The participants in this study were undergraduate students enrolled in one of three courses:

- Programming: This course introduced fundamental programming concepts, including algorithm development, data structures, and software design principles.
- Signal Processing: Students learned techniques for analyzing and manipulating signals, covering Fourier transforms, filtering, and spectral analysis.
- Numerical Analysis and Scientific Computation: This course focused on numerical methods for solving mathematical problems, such as root-finding, interpolation, and differential equations.

3.2 Data Collection

Data were collected using a combination of prospective and retrospective surveys administered to students in each course. A survey was issued to the students at the completion of the scaffold project to understand (4.1) Table 1 - Perceived Student Learning Gains: Pre- and Post-Program Survey, (4.2) Table 2 - Student Perceptions of Project: Post Survey Only, and (4.3) Table 3 - Comparison to Other Courses: Post Survey Only. These instruments allowed for quantitative evaluation of student perceptions, learning outcomes, and the comparative emphasis of course objectives.

3.3 Data Analysis Procedure

Data collected from the assessments were analyzed using IBM SPSS Statistics (version 30.0.0.0). To examine differences in mean scores before and after the intervention, paired t-tests were conducted for each course. The resulting p-values were used to determine the statistical significance of observed changes, with an alpha level of 0.05 indicating significance. This approach allowed for a straightforward comparison of student performance within each course, accounting for the paired nature of the pre- and post-assessment data.

4. Results and Discussion

4.1 Perceived Student Learning Gains: Pre- and Post-Program Survey

Table 1 shows the results of this survey. The perceived student confidence and engagement in collaborative learning gains were measured using a retrospective post-then-pre survey. This section assessed changes in students' comfort, confidence, and engagement before and after completing the course. Paired t-tests were conducted to determine whether the mean differences were statistically significant. Three statements showed statistical significance ($p < 0.05$): information-seeking behavior, peer communication, and written communication. This indicates that the course had a measurable effect on students' autonomous learning habits and communication confidence, which this study deems to be positive. Other aspects, such as comfort with projects and teamwork, increased slightly but not at a statistically significant level. These findings imply that integrating more peer interaction and reflective writing opportunities can further enhance engagement. The results also highlight the value of creating structured, collaborative learning environments that encourage students to take ownership of their academic growth.

Table 1. Retrospective Results for Class Participation: Pre- and Post-Program Survey

1. Indicate the extent to which you agree with each statement both before and after completing this course.			
Statement	BEFORE (average)	AFTER (average)	T-Test (two-sided p-value)
I feel comfortable completing end-of-semester projects.	3.97	4.21	0.13
I seek out a variety of information sources to supplement my learning.	4.08	4.54	*0.003
I enjoy learning the perspectives and opinions of my peers.	4.15	4.26	0.44
I enjoy sharing my perspectives and opinions with my peers.	4	4.32	*0.032
I am confident in my written communication skills.	3.95	4.18	*0.027
I enjoy participating in end-of-semester team projects.	3.82	3.97	0.383

*p-value significance: *<0.05*

4.2 Student Perceptions of Project: Post Survey Only

Table 2 shows the results of this survey. The perceived impacts of the final project's learning gains and skill development were measured using a retrospective post survey. The post-course averages ranged from *3.85* to *4.37*, reflecting generally high satisfaction and perceived learning impact. Students especially agreed that the final project increased their learning (*4.37*) and offered real-world insights (*4.29*). Written communication (*3.88*) and physics application (*3.85*) scored slightly lower, suggesting potential areas for further instructional focus. Overall, students perceived the project as informative, personally meaningful, and conducive to skill development and belonging. These findings imply that authentic, project-based assessments are powerful tools for student engagement. The slightly lower scores in written communication and physics application suggest opportunities to integrate clearer technical writing instruction and applied content connections.

Table 2. Extent of Student Perceptions: Post Survey

2. Please indicate the extent to which you agree with each of the following statements.	
Statement	AFTER (average)
The final project increased my interest in this course.	3.93
The final project increased my learning in this course.	4.37
The final project offered insights for the real-world and my own life.	4.29
The final project was informative.	4.2
The final project improved my written communication skills.	3.88
The team-based aspect of the final project gave me a sense of belonging in the course by getting to know other course participants.	4
The final project offered learning that was important to my self-development.	4.1
The final project expanded my knowledge in physics applications.	3.85
The final project improved my critical thinking skills.	4.15
The final project directions and expectations were easy to understand.	4.2

4.3 Comparison to Other Courses: Post Survey Only

Table 3 shows the results of this survey. The perceived extent to which the course fostered higher-order thinking and appreciation of diverse perspectives was measured using a retrospective post-survey. Students rated the course highly (*mean: 4.12 to 4.46*) in fostering higher-order learning outcomes. The strongest areas were learning beyond the curriculum (*4.46*) and applying learning in new contexts (*4.39*). This suggests that the course was perceived as particularly effective in promoting deep learning, inquiry, and diverse perspectives relative to other courses. The data suggest that continuing to emphasize open inquiry and cross-disciplinary thinking will sustain and deepen these educational benefits.

Table 3. Extent of Educational Application: Post Survey

3. Compared to other courses, to what extent did your learning in this course emphasize the following? (1 = Not at All, 5 = Very Much)	
Statement	**AFTER (average)**
Applying learning in new contexts.	4.39
Learning beyond the curriculum.	4.46
Formulating questions and generating own inquiries.	4.2
Exploring alternatives.	4.39
Encouraging diverse perspectives.	4.2
Understanding diverse perspectives.	4.12

5. Conclusions

The guiding research question is as follows: How does integrating scaffolding improve student perceptions of learning and engagement in undergraduate Electronic Engineering courses?

The results indicate that the three-step scaffolding approach (e.g., project proposal, progress update, and final submission) positively impacts students' autonomous learning behaviors, communication confidence, and perceived depth of learning. Statistically significant gains were observed in information-seeking behavior, peer communication, and written communication, suggesting that structured checkpoints and formative feedback support student growth beyond technical content alone. Additionally, students reported high levels of perceived learning, real-world relevance, and higher-order thinking compared to other courses, directly addressing the guiding research question and supporting the effectiveness of scaffolded project-based learning in ECE contexts.

Based on these findings, several stakeholders can act differently to enhance engineering education practice. Instructors are encouraged to intentionally design projects with clear intermediate milestones and feedback loops rather than relying solely on large, end-of-semester deliverables [10]. Departments and curriculum designers can support this shift by valuing formative assessment, reflective activities, and communication skills alongside technical rigor [11]. Institutions should also consider providing instructional support or workload recognition for faculty implementing scaffolded, student-centered pedagogies, as these approaches require sustained engagement but yield meaningful educational benefits, especially in online environments [12]

This work-in-progress study is limited by its small sample size at a single institution, reliance on self-reported perception data rather than direct performance measures, and the absence of a control group, which constrains generalizability and limits causal claims. Future research should involve larger and more diverse populations across institutions, incorporate longitudinal designs to examine retention, self-efficacy, and professional readiness, and explore optimal levels and fading of scaffolding. Combining perception-based data with objective learning and performance measures would further strengthen the evidence for scaffolding as an effective strategy in electrical and computer engineering education.

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