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Enhancing Student Performance in Engineering Computing: A Comparative Study of Traditional and Research-Integrated Pedagogies

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Abstract
As engineering programs adapt to new technologies and learning needs, there is increasing interest in assessment structures that better support student engagement and skill development. This Work-in-Progress study compares two sections of an introductory Engineering Computing course: one using a traditional assessment model based on homework and exams, and another incorporating quizzes and an eight-week research project through the Research for All (R4A) initiative. Both sections followed the same course content and operated under a structured Generative AI (GenAI) usage policy. Initial survey data (n = 15) show high student agreement regarding engagement, real-world relevance, and responsible AI guidance (≈4.0-4.6/5). Students also reported limited prior programming experience (≈2.7/5). Performance data and qualitative feedback are currently being analyzed. Preliminary trends suggest that diversified assessments and research-integrated learning may strengthen student engagement and perceived learning. Full data analysis will be completed before the conference presentation.

Keywords: Engineering Education, Assessment Strategies, Student Engagement, Computing Pedagogy, Research-Based Learning.

1. Introduction

Engineering education continues to evolve as programs respond to rapid technological growth and changing professional expectations. Traditional assessments mainly homework and high-stakes exams often emphasize procedural learning but may not fully capture skills such as critical thinking, communication, and problem-solving [1, 2]. Active learning strategies, including problem-based and project-based learning, have been widely explored for their ability to increase student participation, deepen conceptual understanding, and connect coursework to real engineering practice [3, 4]. Research-based projects can further support motivation and professional identity formation by giving students authentic engineering tasks [5, 6].
At the same time, the arrival of Generative AI (GenAI) tools has introduced new opportunities and concerns in higher education. While AI can provide personalized support, generate examples, and assist with debugging, its use raises questions about academic integrity, ethics, and equitable access [7–10]. Many institutions now adopt structured AI guidelines to help students use these tools responsibly while maintaining meaningful learning.

This study examines how a diversified assessment structure combining quizzes and a research project compares to a traditional assessment model in an introductory Engineering Computing course. The following research questions guide this work:

1. Does adding quizzes and a research project improve student performance compared to a traditional homework-and-exam model?

2. How do research-based activities influence engagement and skill development?
3. How do structured GenAI usage guidelines shape student learning perceptions?

This Work-in-Progress contributes to growing discussions on assessment innovation, active learning, and responsible AI integration in engineering education.

2. Literature Review

2.1. Active Learning and Diversified Assessments

Engineering programs increasingly adopt active learning approaches that move beyond tool-focused instruction toward challenge-based and situated learning [11]. Restructured introductory computing courses have shown improvements in students' analytical organization and communication skills [11]. Interactive simulations and nonlinear storytelling also enhance motivation by giving students virtual, realistic contexts for practice [12].

Although flipped classrooms remain popular, evidence suggests that learning gains stem primarily from the active components, not the flipped format alone [13, 14]. Collaborative and team-based strategies including communication-focused interventions and two-stage exams have been shown to improve confidence, elaboration, and coordination within engineering teams [15–17]. Psychological safety is another important factor; while short interventions may not yield immediate changes, it remains critical for effective teamwork [18].

Overall, diversified assessments and active learning commonly improve engagement even when exam performance differences are modest [13, 14, 19, 20].

2.2. Research-Based Learning in Engineering

Research-oriented and experiential projects help students connect coursework to real engineering scenarios. Challenge-based freshman computing courses have resulted in higher levels of organization and professional communication [11]. Simulation-based and gamified learning environments also promote relevance and student motivation [12]. Team-oriented interventions further show promise in strengthening collaboration and equitable participation [15].

These experiences are often influential for students' academic pathways and professional identity formation, especially when they involve authentic design tasks and faculty mentorship [11, 20].

2.3. Generative AI in Engineering Education

GenAI has rapidly shifted conversations about teaching and learning since 2022. Scholars note that humans have long created tools to aid cognition [21], and AI represents a new extension of this capability [22]. While GenAI can support content creation, adaptive learning, and problem generation [23], earlier work raised concerns about reliability and the need for human oversight [24].

Recent studies highlight both opportunities and challenges for GenAI in engineering education [25]. Benefits include up-to-date content synthesis, personalized learning, and rapid feedback. Challenges involve data-based biases, ethical considerations, faculty training needs, and infrastructure requirements. As a result, responsible, well-defined AI policies are increasingly emphasized in engineering programs.

3. Methodology

3.1. Course Context

The study was conducted in an introductory Engineering Computing course required for mechanical engineering majors. The course teaches foundational programming concepts in C and Python, computational problem-solving strategies, and engineering applications. Both course sections used identical lectures, materials, and exams. The primary difference between the two sections was the assessment structure:

- **Section 1 (Traditional):** Homework + exams
- **Section 2 (Diversified):** Homework + exams + quizzes + eight-week research project (R4A)

In the diversified section, quizzes and the research project were added to provide additional formative and authentic learning opportunities. Homework volume in the diversified section was modestly reduced (approximately 10–15%) to maintain workload balance while preserving the intended learning outcomes. The goal was to examine whether quizzes and research-based learning provide measurable benefits to engagement and performance.

3.2. R4A Research Project

Students in section 2 completed an eight-week project titled *Static Equilibrium Analysis of Mechanical Linkages*. The project consisted of system selection, literature review, free-body diagram creation, computational implementation in C and Python, result comparison, and error analysis.

The project was structured as a scaffolded research experience. During Weeks 1–2, students identified a mechanical system and revisited core concepts in static equilibrium. Weeks 3–5 focused on algorithm development, model construction, coding, and iterative debugging in C and Python. Weeks 6–8 emphasized validating computational predictions, refining models, interpreting discrepancies, and producing a formal written report and oral presentation. Weekly meetings with graduate mentors supported engineering reasoning, research planning, and troubleshooting, offering a learning environment that reflects early-career engineering research processes.

3.3. Generative AI Usage Policy

Both sections followed an identical GenAI policy. Students were encouraged to use AI tools for studying, debugging, and brainstorming, while generating homework or exam solutions, full project drafts, or complete code using GenAI remained prohibited.
AI usage was documented using a structured reporting form in which students described the tool used, the purpose, and specific information obtained. For any AI-supported coding task, students provided brief written explanations describing their reasoning and modifications. Weekly practice sessions with in-class coding tasks helped verify progression and detect inconsistencies. Research project teams also participated in short oral discussions of modeling and coding decisions, ensuring alignment between submitted work and student understanding.

3.4. Participants

Participants were undergraduate students enrolled in the course. Survey participation was voluntary and anonymous. Demographic information, such as prior programming experience, was collected.

3.5. Data Sources and Analysis

Data sources included:

- **Performance data:** homework, quizzes, exams, and research project scores
- **Survey results:** perceptions of engagement, learning, assessment usefulness, and AI influences
- **Qualitative comments:** open-ended feedback on learning experiences

Planned analyses include descriptive statistics, correlation analysis within Section 2, and thematic analysis for open responses. At the time of writing, data processing is ongoing.

4. Results and Discussion

4.1. Preliminary Survey Findings

Initial survey results were strongly positive across most areas (n = 15). Students generally agreed that the research project was engaging and supported real-world computing connections, with average ratings around 4.0–4.1 out of 5. Students also reported a solid learning experience, including increased motivation and confidence applying computing concepts (averages ~3.7–3.8/5). Engagement and satisfaction ratings were similarly high, and students especially agreed that GenAI guidelines were clear and that using GenAI for allowed tasks improved understanding, with the highest average scores in the survey (around 4.4–4.6/5). The only area showing comparatively lower agreement was prior experience with programming/computing, suggesting many students entered the course with limited background (average ~2.7/5).

4.2. Expected Outcomes

Based on the literature and preliminary feedback, the following outcomes are anticipated:

- **Higher engagement** in the diversified section due to quizzes and authentic research tasks
- **More consistent learning progression** from weekly formative assessments
- **Improved conceptual connections** through the research project
- **Positive but bounded influence of AI**, with students using it responsibly rather than as a shortcut

Full quantitative and qualitative analysis will be completed before the conference.

5. Conclusion and Future Work

This Work-in-Progress study compares traditional and diversified assessment models in an introductory Engineering Computing course. Initial findings suggest that incorporating quizzes and a research project may enhance engagement, perceived relevance, and confidence, though performance analysis is ongoing. Responsible GenAI use appeared to support learning without compromising integrity.

Future work will expand the study across additional semesters and course contexts. Planned analyses include long-term retention, subgroup comparisons, and the impacts of AI literacy on learning behaviors. Continued refinement of diversified assessment strategies may help engineering programs better prepare students for modern computational practice.

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