WIP: Curriculum Reform and Engineering Software Integration for Student Outcomes and Continuous Improvement in a Civil Engineering Program

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Abstract

Rapid technological change and evolving industry expectations require civil engineering programs to continuously align curricula, instructional resources, and assessment systems with professional practice. Following an extensive self-study, a civil engineering program implemented a coordinated curriculum reform and expanded integration of engineering software beginning in Fall 2024. While such reforms are increasingly common, their measurable impact on ABET Student Outcomes and the effectiveness of continuous improvement processes remains underexplored.

This Work-in-Progress study evaluates the early effects of curriculum reform and engineering software integration on selected ABET Student Outcomes (SO 1 – Problem Solving, SO 2 – Engineering Design, SO 5 – Teamwork, and SO 6 – Experimentation and Data Analysis) and examines how these changes influence the program's continuous improvement cycle. Guided by outcome-based assessment principles and an ABET-aligned continuous improvement framework, a mixed-methods quasi-experimental design compares pre-reform (Fall 2021 to Spring 2024) and post-reform (Fall 2024 to Spring 2025) assessment evidence. Quantitative data are drawn from aggregated course-level outcome indicators and assessment summaries, while qualitative data include faculty reflections and stakeholder feedback.

Preliminary findings indicate early improvements in student performance in problem solving and experimentation and data analysis, alongside identified performance gaps in engineering design and teamwork that continue to inform targeted instructional refinement. Additional findings suggest improved consistency in outcome measurement and enhanced clarity and usability of assessment data within the continuous improvement process. This study contributes an evidence-informed evaluation approach for civil engineering programs seeking to integrate digital tools while maintaining rigorous, ABET-aligned assessment and continuous improvement practices.

Keywords: Curriculum Reform, Engineering Software, Student Outcomes, Continuous Improvement, Civil Engineering Education, ABET, HBCU

1. Introduction

Preparing civil engineers for contemporary and future practice requires more than mastery of foundational theory. Entry-level engineers are increasingly expected to apply engineering principles using advanced computational tools, evaluate open-ended design problems, and collaborate effectively within multidisciplinary teams. These expectations reflect the realities of modern civil engineering practice, where digital modeling, simulation, and data-driven decision-making are integral to professional work. Accreditation frameworks such as ABET formalize these expectations through clearly defined Student Outcomes that emphasize problem solving, engineering design, teamwork, experimentation, and continuous learning [1].

While ABET provides a common framework for defining desired graduate competencies, translating these outcomes into effective curricular experiences remains a persistent challenge for engineering educators. Many programs have undertaken curriculum reforms aimed at modernizing instruction through the introduction of engineering software, design-oriented coursework, and active learning strategies [2]. Prior research suggests that such reforms can enhance student engagement and professional readiness when digital tools are intentionally embedded within problem-based and design-focused learning activities [3], [4]. However, the literature also indicates that the educational impact of these changes varies considerably across institutions and depends strongly on the degree of alignment among instructional innovations, assessment practices, and performance expectations [5].

A recurring limitation in engineering education research is the tendency to document implemented curricular changes without systematically examining how those changes influence student learning and outcome attainment at the program level. As a result, programs may adopt new tools and instructional approaches without clear evidence of whether they improve attainment of ABET Student Outcomes or simply increase instructional complexity. This disconnect can undermine the effectiveness of continuous improvement processes, reducing them to procedural compliance activities rather than mechanisms for evidence-based decision-making and educational enhancement [5], [6].

In Fall 2024, a civil engineering program at a Historically Black College and University implemented a comprehensive curriculum reform designed to address this gap. Rather than introducing engineering software as a supplementary skill, the reform intentionally integrated digital tools into the structure of core and design-oriented courses, with explicit alignment to mapped Student Outcomes and established assessment criteria. The reform was supported by enhanced instructional computing resources and refinements to course deliverables to emphasize modeling, analysis, and design justification.

This study examines the early effects of curriculum reform and engineering software integration on student learning and the operation of the program's continuous improvement process. Moving beyond descriptive accounts of curricular change, the study focuses on outcome-linked evidence and assessment dynamics during the initial implementation period. The study is guided by the following research questions:

- **RQ1:** Is there a measurable difference in the attainment of selected ABET Student Outcomes between pre-reform and post-reform student cohorts?
- **RQ2:** Does the curriculum reform improve the clarity, consistency, and actionability of assessment data within the continuous improvement process?
- **RQ3:** Which aspects of the reform do faculty perceive as most effective in supporting student readiness for professional civil engineering practice?

2. Literature Review and Conceptual Framework

2.1 Curriculum Reform and Digital Transformation in Civil Engineering Education

Civil engineering education continues to evolve in response to rapid technological advancement and changing professional expectations, particularly the increasing reliance on computational tools, modeling, and data-driven decision-making. Entry-level civil engineers are now expected to analyze complex systems, evaluate multiple design alternatives, and justify decisions using digital workflows that reflect contemporary industry practice. As a result, academic programs face growing pressure to ensure that curricula remain aligned with these realities while maintaining strong theoretical and analytical foundations [3].

Curriculum reform has emerged as a primary mechanism for addressing these challenges. Prior research indicates that reforms emphasizing integrated design experiences, authentic engineering problems, and active learning strategies can enhance student engagement and conceptual understanding when implemented coherently [4], [7]. However, the effectiveness of such reforms varies across institutions. Studies consistently show that curricular changes yield the greatest impact when instructional innovations are explicitly aligned with clearly defined learning outcomes and supported by systematic, program-level assessment practices [8].

2.2 Engineering Software Integration and Student Learning

The integration of engineering software into undergraduate civil engineering curricula is widely recognized as an essential component of preparation for contemporary professional practice. Industry-relevant tools enable students to visualize complex systems, perform iterative analyses, and evaluate design alternatives in ways that extend beyond traditional analytical methods. Prior studies indicate that meaningful exposure to such tools can enhance students' problem-solving skills, spatial reasoning, and perceived professional readiness, particularly when software use is embedded within authentic engineering problems rather than taught in isolation [9].

Despite these potential benefits, the literature cautions that software integration alone does not guarantee improved learning outcomes. Without intentional instructional design, students may focus on procedural execution rather than conceptual understanding, thereby limiting the educational value of digital tools. Effective implementations emphasize scaffolded learning activities, explicit alignment with learning outcomes, and performance-based assessment strategies to ensure that software use supports deeper learning and knowledge transfer [4], [7].

At the program level, however, empirical evidence linking engineering software integration to measurable improvements in ABET Student Outcome attainment across multiple courses and semesters remains limited. This gap highlights the need for systematic evaluation approaches that move beyond course-level perceptions and examine the broader impact of software-supported curriculum reform on student learning and continuous improvement processes [5], [8].

2.3 Outcome-Based Assessment and Continuous Improvement

Outcome-based assessment and continuous improvement are foundational components of ABET accreditation. Accredited engineering programs are required to define measurable Student Outcomes, assess student performance using appropriate instruments, and use assessment results to inform curricular and instructional decisions through documented and iterative processes [1]. In principle, this framework enables programs to respond to evolving professional expectations while maintaining accountability and transparency.

In practice, however, engineering education research has identified persistent challenges in implementing effective continuous improvement systems. Common issues include inconsistent application of performance criteria across courses, limited faculty engagement with assessment data, and difficulty translating assessment results into actionable improvement strategies [5], [6]. These challenges may be amplified during periods of curriculum reform, when multiple instructional and structural changes occur simultaneously and attribution of observed effects becomes more complex.

Recent studies emphasize the importance of integrating assessment design into curriculum reform efforts from the outset. When learning activities, instructional tools, and assessment instruments are coherently aligned, continuous improvement processes are more likely to support meaningful, data-informed decision-making rather than procedural compliance alone [8].

2.4 Conceptual Framework and Theoretical Foundations

Building on the literature reviewed in Sections 2.1 through 2.3, this study is guided by a conceptual framework that integrates Human Capital Theory with an ABET-aligned continuous improvement framework to examine the early effects of curriculum reform and engineering software integration on student learning and assessment processes.

Human Capital Theory posits that investments in education and skill development enhance individuals' productivity, adaptability, and long-term professional value [10]. Within the context of civil engineering education, curriculum reform and access to engineering software represent intentional educational investments aimed at strengthening students' technical competencies, design readiness, and applied problem-solving skills. From this perspective, embedding digital tools within core coursework is expected to support students' ability to apply engineering knowledge in authentic contexts and to transition more effectively into professional practice.

Complementing this theoretical lens, the ABET-aligned continuous improvement framework emphasizes iterative cycles of assessment, reflection, and action as mechanisms for sustaining educational quality. Within this framework, student performance data serve as primary inputs for identifying gaps between intended and observed outcomes and for guiding targeted instructional and curricular adjustments [1]. Consistent with the challenges identified in Section 2.3, reforms that improve alignment among learning activities, digital tools, and assessment instruments are expected to influence not only student outcome attainment but also the clarity, consistency, and usability of assessment data supporting the continuous improvement process [5], [8].

Figure 1 presents the conceptual framework guiding this study. Curriculum reform and engineering software integration function as educational inputs that shape instructional implementation through software-embedded coursework, design-oriented assignments, and outcome-aligned assessment practices. Student learning outcomes are evaluated using established program assessment instruments, and the resulting evidence informs a structured continuous improvement process. As illustrated in Figure 1, assessment evidence feeds back through iterative loops to guide subsequent curriculum reform, instructional strategies, and resource investments, supporting systematic evaluation and data-informed program refinement over time.

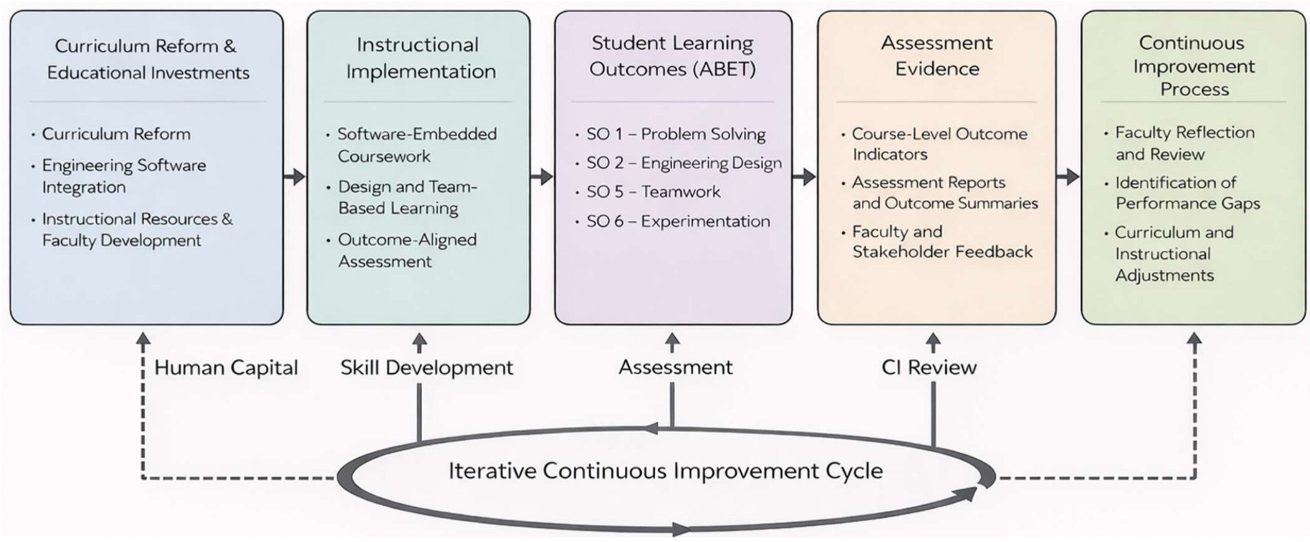

Figure 1. Conceptual Framework Linking Curriculum Reform, Engineering Software Integration and Continuous Improvement

3. Methodology

3.1 Study Design

This study adopts a mixed-methods, quasi-experimental design to evaluate the early effects of curriculum reform and engineering software integration on student learning outcomes and the operation of the program's continuous improvement process. Student performance and assessment data from pre-reform cohorts are compared with those from post-reform cohorts to examine changes associated with the implemented interventions. Random assignment was not feasible due to program-wide implementation, making a quasi-experimental approach appropriate.

3.2 Institutional Context and Reform Implementation

The study was conducted within an undergraduate civil engineering program at a Historically Black College and University. Beginning in Fall 2024, the program implemented a coordinated curriculum reform to strengthen the integration of engineering software within core and design-oriented courses. In this study, engineering software refers to discipline-specific computational, modeling, and analysis tools embedded within coursework and assessed using ABET-aligned performance criteria.

As documented in the program's ABET self-study and course syllabi, these tools are incorporated progressively across the curriculum, beginning with foundational computational and programming tools such as MATLAB in CEGR 307 (Computer Methods and Programming for Civil Engineering), followed by domain-specific modeling tools such as HEC-RAS for hydraulic analysis in CEGR 332 (Hydraulic Engineering) and computational simulation platforms such as ANSYS and FLUENT in CEGR 214 (Fluid Mechanics and Laboratory).

At the senior level, students apply design and analysis tools such as RISA or SAP2000 and project management software such as Microsoft Project in design-oriented and capstone courses, along with geospatial and remote sensing tools such as ArcGIS and ENVI in specialized electives. The Fall 2024 reform placed greater emphasis on embedding these tools directly into course assignments, laboratory activities, and design projects through coordinated faculty implementation aligned with mapped Student Outcomes.

3.3 Data Sources and Participants

Data were drawn from multiple student cohorts spanning both pre- and post-reform periods. Quantitative data sources included course-level Student Outcome assessment results, Faculty Course Assessment Reports (FCARs), and aggregated program-level outcome summaries. Where available, internship participation records were also reviewed to contextualize outcome attainment. Qualitative data sources consisted of faculty reflections documented during assessment review cycles and feedback from the program's Industrial Advisory Board (IAB). All data were collected as part of routine ABET-aligned assessment activities.

3.4 Outcome Measures

The analysis focused on ABET Student Outcomes most directly influenced by software-embedded instruction and design-oriented learning activities, including problem solving (SO 1), engineering design (SO 2), teamwork (SO 5), and experimentation and data analysis (SO 6). Each outcome was assessed using established performance criteria and rubrics applied consistently across mapped courses. Course-level results were aggregated to the program level to support comparative analysis.

3.5 Analysis Procedures

Quantitative analysis involved descriptive and comparative examination of Student Outcome attainment across pre- and post-reform cohorts, with emphasis on trends, changes in average performance, and variability across courses and semesters. Given the early stage of reform implementation, the analysis focused on directional patterns rather than inferential statistical testing. Qualitative data were reviewed thematically to identify faculty-perceived impacts on student learning, assessment clarity, and instructional decision-making, supporting interpretation of the quantitative findings.

3.6 Continuous Improvement Evaluation

In addition to student learning outcomes, the study evaluated the functioning of the program's continuous improvement process during the post-reform period. This evaluation examined the clarity and consistency of assessment evidence, faculty engagement with outcome data, and documentation of resulting curriculum and instructional adjustments. This process-focused analysis supports assessment of how curriculum reform influences both outcome attainment and the effectiveness of the continuous improvement framework.

3.7 Ethical Considerations

All data used in this study were de-identified prior to analysis and are reported in aggregate form. The analysis relied exclusively on existing academic assessment data collected as part of routine program evaluation and accreditation activities.

Table 1 provides a summary of the study design, data sources, and analysis approach used to evaluate the early effects of curriculum reform and engineering software integration on student learning outcomes and continuous improvement processes.

Table 1. Summary of Study Design, Data Sources and Analysis Approach

Component	Description
Study Design	Mixed-methods, quasi-experimental evaluation
Evaluation Periods	Pre-reform: Fall 2021 – Spring 2024; Post-reform: Fall 2024 – Spring 2025
Institutional Context	Undergraduate civil engineering program at a Historically Black College and University
Intervention	Curriculum reform with embedded engineering software integration in core and design-oriented courses
Student Outcomes Evaluated	ABET Student Outcomes: SO 1 (Problem Solving), SO 2 (Engineering Design), SO 5 (Teamwork), SO 6 (Experimentation and Data Analysis)

Quantitative Data Sources	Course-level Student Outcome assessments; Faculty Course Assessment Reports; aggregated program-level outcome summaries
Qualitative Data Sources	Faculty reflections from assessment review cycles; Industrial Advisory Board feedback
Analysis Approach	Descriptive and comparative analysis of outcome attainment; thematic review of qualitative feedback
Continuous Improvement Focus	Evaluation of assessment clarity, faculty engagement, and documentation of curriculum and instructional adjustments

4. Preliminary Results and Early Indicators

This section presents preliminary outcome evidence drawn from the program's ABET continuous improvement documentation, with emphasis on early indicators associated with the initial implementation of curriculum reform and engineering software integration. Results are evaluated against the program's established attainment threshold and are interpreted as indicative trends rather than definitive effects.

The findings are organized in relation to the three research questions guiding this study: (RQ1) changes in ABET Student Outcome attainment, (RQ2) changes in the clarity and usability of assessment data within the continuous improvement process, and (RQ3) faculty perceptions of the effectiveness of the implemented curriculum reform.

4.1 Student Outcome Attainment Relative to Benchmark

The program defines satisfactory attainment as at least 75% of students performing at the satisfactory or exemplary level for each assessed Student Outcome. Semester-level outcome summaries reported in the continuous improvement documentation provide a basis for comparing pre-reform and post-reform performance trends.

For outcomes most directly aligned with software-embedded instruction, observable improvements are noted following reform implementation. Average attainment for SO 1 (Problem Solving) increased from 83.77% across pre-reform semesters (Fall 2021 to Spring 2024) to 93.56% across post-reform semesters (Fall 2024 to Spring 2025). Similarly, SO 6 (Experimentation and Data Analysis) increased from a pre-reform average of 92.65% to 95.11% during the post-reform period. In both cases, attainment exceeded the program benchmark in all reported post-reform semesters.

These findings indicate early improvements in students' ability to apply engineering principles, analyze computational results, and engage in data-informed problem solving within software-supported learning environments.

4.2 Identification of Performance Gaps

In addition to areas of improvement, the assessment data identify semesters in which selected outcomes did not meet the attainment benchmark. Notably, SO 5 (Teamwork) fell below the 75% threshold in multiple pre-reform semesters, including Fall 2021 (60.00%) and Spring 2024 (69.00%). Similarly, SO 2 (Engineering Design) fell below the benchmark in Spring 2024 (70.59%).

The presence of these shortfalls highlights the functioning of the program's continuous improvement process, enabling targeted instructional and curricular adjustments following the identification of performance gaps. These findings reinforce the role of structured assessment review as a mechanism for guiding reform priorities, rather than serving solely as a compliance activity.

4.3 Summary of Extracted Preliminary Outcomes

Table 2 summarizes the extracted preliminary outcome evidence for the Student Outcomes examined in this study, highlighting differences between pre-reform and post-reform periods. Reported values represent average attainment across available semesters within each period.

Table 2. Summary of Pre-Reform and Post-Reform Student Outcome Attainment Relative to Benchmark

Student Outcome	Pre-Reform Mean (%) (Fall 2021–Spring 2024)	Post-Reform Mean (%) (Fall 2024–Spring 2025)	Benchmark (%)
SO 1 – Problem Solving	83.77	93.56	75
SO 6 – Experimentation and Data Analysis	92.65	95.11	75
SO 2 – Engineering Design	70.59*	Not yet available	75
SO 5 – Teamwork	69.00*	Not yet available	75

**Indicates semester-level attainment values below the 75% benchmark during the pre-reform period.*

4.4 Continuous Improvement Process Indicators

Beyond outcome attainment, the assessment documentation indicates improvements in the clarity and usability of assessment evidence during post-reform review cycles. Faculty Course Assessment Reports demonstrate more explicit linkage between assignments, performance criteria, and Student Outcomes, reflected in clearer mapping of course deliverables to outcome indicators and more detailed justification of outcome ratings in courses incorporating software-based deliverables. Faculty review discussions increasingly focused on identifying specific performance gaps and corresponding instructional responses, rather than on interpreting assessment metrics.

These early process-level indicators are consistent with the conceptual framework's expectation that curriculum reform and software integration can strengthen both student learning and the effectiveness of continuous improvement mechanisms.

4.5 Summary of Early Findings

Overall, preliminary findings indicate positive early effects of curriculum reform and engineering software integration on both student learning and assessment processes. While the magnitude of observed changes remains modest and additional longitudinal data are required to assess sustained impact, early indicators suggest improvements in selected Student Outcome attainment, greater consistency and clarity in assessment evidence, and enhanced effectiveness of the continuous improvement process. These findings provide a foundation for continued evaluation and inform the discussion of implications and next steps presented in the following section.

5. Discussion and Implications for Continuous Improvement

This section interprets the preliminary findings in relation to the study's conceptual framework and examines their implications for continuous improvement within the civil engineering program. Consistent with the framework, the discussion considers both student learning outcomes and the functioning of the assessment-driven improvement process.

5.1 Interpretation of Student Outcome Trends (RQ1)

The observed improvements in Student Outcomes related to problem solving (SO 1) and experimentation and data analysis (SO 6) are consistent with the increased integration of engineering software into core and design-oriented coursework. Software-embedded assignments provided students with opportunities to engage in iterative analysis, visualize system behavior, and evaluate design alternatives, which are central to these outcomes. From a Human Capital Theory perspective, these curricular investments appear to support the early development of technical competencies aligned with contemporary professional practice.

In contrast, outcomes related to engineering design (SO 2) and teamwork (SO 5) exhibited documented performance gaps during the pre-reform period, underscoring the complexity of developing higher-order design and collaborative skills. These findings suggest that while software integration may support analytical competencies, sustained attention to instructional design, scaffolding, and team dynamics remains necessary to achieve comparable improvements in these areas.

5.2 Implications for Assessment and Continuous Improvement Processes (RQ2)

Beyond outcome attainment, the findings highlight important implications for the program's continuous improvement process. Post-reform assessment evidence was observed to be clearer and more actionable during faculty review cycles, facilitating more focused discussions on performance gaps and targeted instructional responses. This shift supports the premise that alignment among learning activities, digital tools, and assessment instruments enhances not only student learning but also the usability of assessment data.

The identification of performance gaps in specific outcomes demonstrates the value of systematic assessment in guiding improvement efforts. Rather than indicating shortcomings of the reform, these gaps provide actionable insights that inform curriculum and instructional adjustments. This reinforces the role of continuous improvement as an iterative, evidence-driven process rather than a compliance-oriented exercise.

5.3 Program-Level Implications and Faculty Perspectives (RQ3)

At the program level, these findings suggest that curriculum reform and engineering software integration can serve as effective levers for strengthening both educational quality and assessment practices when implemented within an ABET-aligned framework. The ability to document early gains alongside identified areas for improvement supports more transparent and data-informed decision-making. For programs operating in resource-constrained environments, particularly those serving diverse student populations, this approach offers a structured pathway for aligning innovation with accountability. Early faculty observations further indicate that software-embedded assignments and design-oriented activities are perceived as contributing to student readiness for professional practice, although continued evaluation is needed to assess the consistency of these perceptions over time.

5.4 Limitations and Considerations

Several limitations should be considered when interpreting these findings. First, the post-reform evaluation period is limited, and not all Student Outcomes have complete post-reform data available at the time of analysis. Second, the quasi-experimental design limits causal attribution, as observed changes may be influenced by cohort characteristics or concurrent instructional initiatives. Third, the analysis relies on existing assessment instruments, which may vary in sensitivity across courses.

Additionally, early pre-reform data include semesters affected by hybrid and modified instructional delivery due to the COVID-19 pandemic, which may have influenced student performance in outcomes such as teamwork and engagement. These contextual factors are acknowledged as potential sources of variability in the baseline data. The analysis period also spans the emergence of generative AI tools such as ChatGPT, which may influence student learning behaviors and assessment outcomes. While this study does not isolate these effects, their potential impact is acknowledged as part of the evolving educational context.

These limitations highlight the need for continued data collection and longitudinal analysis to more fully assess the sustained impact of the reform.

5.5 Implications for Ongoing Improvement

Despite these limitations, the findings provide actionable guidance for ongoing improvement. The documented gains in analytical outcomes support continued integration of software-embedded instruction, while identified gaps in design and teamwork outcomes point to areas for targeted instructional enhancement. Continued refinement of assessment practices and faculty collaboration will be critical to sustaining momentum and ensuring that curriculum reform translates into durable improvements in student learning.

At a broader level, these findings have implications for civil engineering programs seeking to modernize curricula under resource constraints. The integration of widely accessible engineering software, combined with structured alignment of assessment practices, provides a scalable approach for enhancing both student learning and continuous improvement processes. This approach is particularly relevant for programs serving diverse student populations, where targeted curricular investments can support both equity and workforce readiness.

6. Conclusion and Future Work

This Work-in-Progress study examined the early effects of curriculum reform and engineering software integration on student learning outcomes and continuous improvement processes within an undergraduate civil engineering program. Guided by Human Capital Theory and an ABET-aligned continuous improvement framework, the study leveraged existing assessment evidence to evaluate preliminary outcome trends and process-level indicators associated with the initial implementation period.

Preliminary findings indicate positive early trends in Student Outcomes related to problem solving and experimentation and data analysis, along with improved clarity and usability of assessment evidence during continuous improvement review cycles. At the same time, documented performance gaps in design and teamwork outcomes highlight areas requiring continued instructional focus and targeted curricular refinement. These findings reinforce the value of systematic, outcome-based assessment in supporting evidence-informed program improvement.

Future work will extend this analysis across additional assessment cycles to evaluate the persistence of observed trends and to capture post-reform data for all relevant Student Outcomes. Planned efforts include incorporating longitudinal outcome tracking, examining course-level implementation fidelity, and refining assessment instruments to improve sensitivity to higher-order design and teamwork competencies. Collectively, these efforts will support a more robust evaluation of curriculum reform impacts and inform sustained, data-driven improvement within the program.

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