Closing the Teamwork and Ethics Gap through Structured Interventions in Civil Engineering Education

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Abstract

Persistent gaps in teamwork (ABET Student Outcome 5) and ethical responsibility (ABET Student Outcome 4) continue to challenge civil engineering programs, even within established outcomes-based assessment systems. At the study institution, longitudinal assessment data revealed fluctuating attainment in teamwork and a decline in ethics performance below the program's 75 percent benchmark during the 2022 academic year. These trends prompted structured instructional refinements within existing coursework aimed at strengthening professional competency development.

Guided by two research questions focused on longitudinal attainment patterns, this study employs a longitudinal descriptive design using aggregated, program-level rubric-based assessment data collected across multiple academic terms from Fall 2021 through Fall 2024. Instructional refinements included calibrated teamwork rubrics, redesigned team structures with reduced group sizes, and embedded ethics case discussions within technical design assignments. Outcome attainment was defined as the combined percentage of students achieving Satisfactory or Exemplary performance levels relative to the program benchmark.

Results document reductions in unsatisfactory ratings and increased concentration of student performance in satisfactory and exemplary categories across successive assessment cycles, particularly for Student Outcome 5. Ethics attainment trends show recovery and stabilization following an initial decline, with later assessment terms meeting or exceeding the program benchmark. Although variability across terms remains, the longitudinal patterns indicate directional movement toward higher attainment categories within the program's continuous improvement framework.

This study illustrates how longitudinal analysis of ABET-aligned assessment data can inform structured instructional refinement within civil engineering curricula. The findings provide a program-level model for integrating teamwork and ethics development into technical coursework while maintaining alignment with accreditation expectations.

Keywords: teamwork; ethics; ABET student outcomes; continuous improvement; civil engineering education; longitudinal assessment.

1. Introduction

Professional competencies such as teamwork and ethical responsibility are essential to civil engineering practice and are explicitly emphasized in ABET accreditation criteria. ABET Student Outcome 5 requires graduates to function effectively on teams, while Student Outcome 4 requires graduates to recognize ethical and professional responsibilities in engineering situations and make informed judgments [1]. Although technical outcomes often demonstrate stable attainment patterns, professional competencies such as teamwork and ethics frequently exhibit greater variability across assessment cycles.

Prior research in engineering education has identified teamwork and ethics as among the most challenging outcomes to develop and assess consistently [2], [3]. These competencies are context-dependent, socially mediated, and sensitive to instructional design. When addressed implicitly or inconsistently within technical coursework, attainment patterns may fluctuate and fall below established program benchmarks.

Consequently, improving professional outcomes often requires intentional alignment among instructional strategies, assessment tools, and program-level continuous improvement processes.

At the study institution, longitudinal ABET assessment data revealed inconsistent attainment trends in Student Outcome 5 and a decline in Student Outcome 4 performance below the program's 75 percent benchmark during the 2022 academic year. These findings indicated a need for structured instructional refinement within existing courses rather than the addition of standalone professional skills modules. In response, the civil engineering program implemented a set of targeted interventions, including calibrated teamwork rubrics, redesigned team structures with smaller group sizes, and embedded ethics-focused case discussions integrated into technical design assignments.

The purpose of this study is to examine longitudinal attainment trends associated with these structured instructional interventions. Rather than making causal claims, the study analyzes program-level rubric-based assessment data collected across multiple academic terms to identify directional changes in performance distributions before and after intervention implementation. By leveraging existing ABET-aligned assessment processes, the study positions continuous improvement as an instructional design mechanism rather than a compliance exercise.

Accordingly, this study addresses the following research questions:

- **RQ1:** How do longitudinal attainment distributions for ABET Student Outcome 5 (Teamwork) compare across pre-intervention and post-intervention assessment terms?
- **RQ2:** How do longitudinal attainment distributions for ABET Student Outcome 4 (Ethics and Professional Responsibility) compare across pre-intervention and post-intervention assessment terms?

Through longitudinal descriptive analysis of outcome distributions, this study contributes evidence on attainment patterns associated with assessment-informed instructional refinement in civil engineering education.

2. Related Work and Theoretical Framework

2.1 Related Work on Teamwork and Ethics in Civil Engineering Education

Teamwork and ethical responsibility are recognized as core professional competencies in engineering education and are explicitly embedded in ABET accreditation criteria [1]. Despite this emphasis, prior research consistently identifies these outcomes as among the most challenging to develop and assess in undergraduate engineering programs. Shuman et al. argue that professional skills require intentional instructional design rather than indirect exposure through technical coursework [2], while Passow and Passow highlight persistent gaps in emphasis on teamwork and ethical reasoning relative to technical competencies [3].

Empirical studies demonstrate that unstructured team assignments often result in unequal participation and limited collaboration skill development. Research on team-based learning indicates that smaller teams, explicit role definition, and structured peer assessment can improve accountability and collective performance [5]. Similarly, scholarship on engineering ethics education suggests that embedding ethical reasoning within discipline-specific design contexts is more effective than isolated instructional modules [6], [7].

Assessment practices further influence outcome stability. Inconsistent rubric interpretation among faculty can reduce reliability and limit the usefulness of assessment data for continuous improvement [8]. Collectively, the literature indicates that strengthening teamwork and ethics attainment requires structured instructional alignment, calibrated assessment practices, and integration of professional reasoning within authentic civil engineering coursework.

2.2 Theoretical Framework

This study is informed by constructivist learning theory, which conceptualizes learning as an active, socially mediated process in which knowledge develops through interaction, collaboration, and reflection. From this perspective, teamwork competencies emerge through structured engagement with peers, negotiated roles, and shared problem-solving rather than passive exposure to technical content. Designing learning environments that promote coordinated decision-making and mutual accountability is, therefore central to professional skill development.

The study also draws on Kolb's experiential learning model, which frames learning as a cyclical process involving concrete experience, reflective observation, abstract conceptualization, and active experimentation [4]. This model is particularly relevant to teamwork and ethics, as it emphasizes structured experiences followed by deliberate reflection that connects action with professional reasoning and judgment.

Consistent with these theoretical perspectives, the instructional refinements examined in this study were designed to create structured collaborative experiences and embed ethical reasoning within discipline-specific coursework. This theoretical grounding provides a lens for interpreting observed changes in outcome attainment.

2.3 Conceptual Framework of the Study

Figure 1 presents the conceptual framework linking assessment-identified performance gaps in teamwork (SO5) and ethical responsibility (SO4) to structured instructional refinement within an ABET-aligned continuous improvement cycle.

Longitudinal assessment data indicating inconsistent teamwork performance and sub-threshold ethics attainment informed targeted program-level adjustments, including calibrated teamwork rubrics, redesigned team structures, and integration of ethics-focused discussions within designated civil engineering courses.

These instructional refinements are intended to support collaborative engagement, role clarity, accountability, and reflective judgment within authentic engineering contexts. Through repeated engagement in team-based design activities and ethics-integrated assignments, students develop competencies associated with communication, coordination, and professional responsibility.

The framework culminates in program-level attainment patterns for SO4 and SO5, with assessment results informing ongoing instructional refinement across successive assessment cycles.

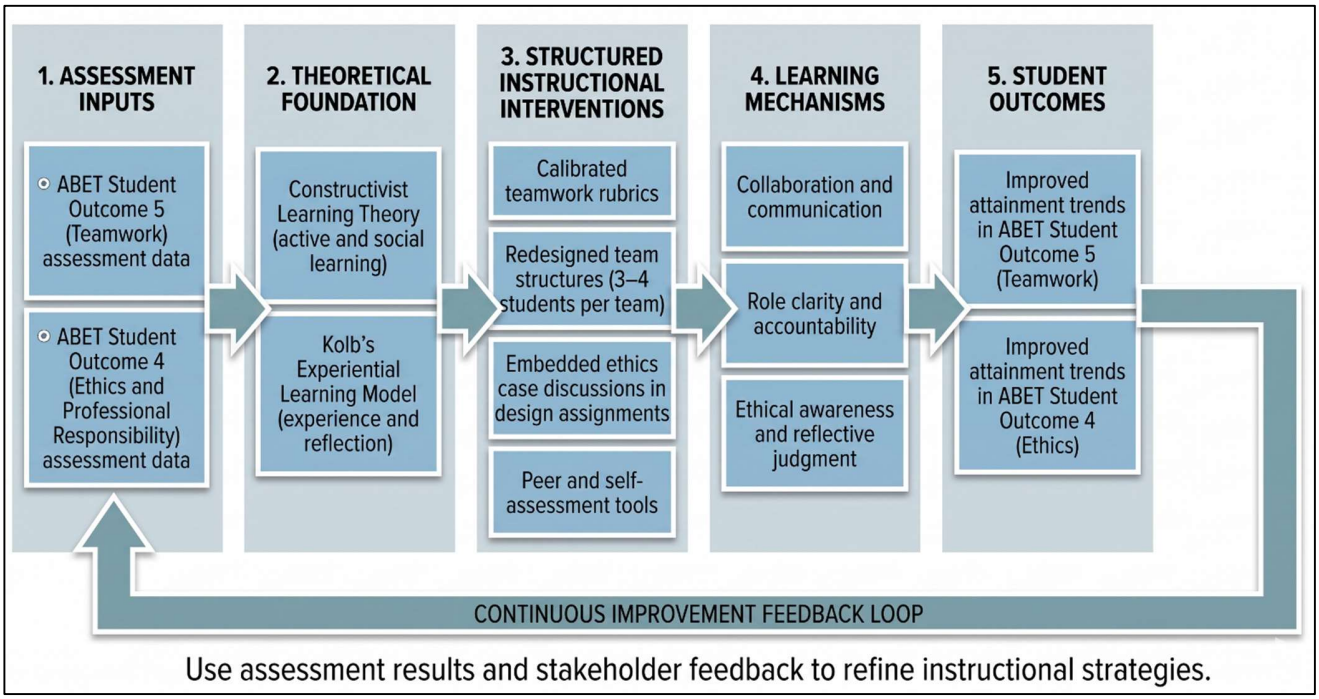


Figure 1. Conceptual framework linking assessment gaps, instructional interventions, learning mechanisms, and outcome attainment within an ABET-aligned continuous improvement process.

3. Methodology

3.1 Research Design

This study employs a longitudinal descriptive design to examine trends in program-level attainment of ABET Student Outcomes 4 (Ethics and Professional Responsibility) and 5 (Teamwork) before and after the implementation of structured instructional refinements. The analysis compares aggregated outcome distributions across multiple academic terms using rubric-based assessment data collected through the program's established ABET-aligned assessment process.

Because the instructional refinements were implemented at the program level within existing courses, random assignment and experimental control were not feasible. Accordingly, the study emphasizes descriptive analysis of longitudinal patterns rather than causal inference. Observed changes are therefore interpreted as temporal patterns in outcome attainment rather than direct treatment effects.

3.2 Study Context and Participants

The study was conducted within an undergraduate civil engineering program at a U.S. institution operating under an outcomes-based assessment and continuous improvement framework. Data were drawn from designated required core civil engineering courses that serve as primary ABET assessment points for Student Outcomes 4 (Ethics and Professional Responsibility) and 5 (Teamwork). These courses are consistently included in the program's assessment cycle across academic terms, although instructor assignments and cohort composition may vary.

The courses span multiple levels of the curriculum and include structured team-based design assignments and ethics-integrated activities. The unit of analysis is program-level aggregated student performance distributions rather than individual student-level trajectories. Cohorts represent successive academic terms

across the study period. Because outcome data are aggregated at the course and program levels, the analysis reflects overall attainment patterns rather than individual progression.

Faculty teaching these courses participated in rubric calibration and alignment activities to promote consistency of assessment implementation across sections. No individual faculty performance data were analyzed; calibration efforts were used solely to support standardization of scoring practices during the study period.

3.3 Instructional Interventions

Consistent with the conceptual framework presented in Figure 1, the study examined a set of structured instructional interventions designed to address assessment-identified gaps in teamwork and ethics attainment. The interventions included:

i. Calibrated teamwork rubrics, developed and aligned across courses to improve consistency in assessment of collaboration, contribution, and conflict resolution

ii. Redesigned team structures, with team sizes limited to three to four students to enhance accountability and role clarity

iii. Embedded ethics case discussions, integrated within design assignments to situate ethical reasoning in discipline-specific contexts

iv. Peer and self-assessment tools, incorporated to support structured evaluation of team performance.

These interventions were integrated into existing course structures as part of the program's ABET-aligned continuous improvement process rather than introduced as standalone instructional modules.

3.4 Intervention Timeline

Structured instructional interventions were implemented following identification of attainment variability in Student Outcomes 4 and 5 during the program's regular assessment review cycle. Fall 2021 represents the primary pre-intervention baseline term. Implementation occurred within designated assessment courses as part of the program's continuous improvement process, with subsequent academic terms reflecting assessment cycles after implementation and stabilization of instructional refinements.

3.5 Data Sources and Collection

Data were drawn exclusively from the program's established ABET outcomes assessment system. Table 1 summarizes the alignment among instructional interventions, targeted student outcomes, and assessment methods.

Quantitative data consisted of rubric-based performance distributions associated with Student Outcomes 4 (Ethics and Professional Responsibility) and 5 (Teamwork). These data were collected across multiple academic terms as part of the program's regular assessment cycle. Performance levels were categorized as Unsatisfactory, Developing, Satisfactory, or Exemplary according to standardized rubric criteria.

All data were anonymized and aggregated at the course and program levels prior to analysis. The study therefore examines longitudinal trends in outcome attainment distributions rather than individual student trajectories.

Table 1. Alignment of instructional interventions, assessment methods, and ABET outcomes

Instructional Intervention	ABET Outcome	Assessment Method	Data Type
Calibrated teamwork rubrics	SO5 (Teamwork)	Rubric-based performance scores	Quantitative
Embedded ethics case discussions	SO4 (Ethics)	Design assignment rubrics	Quantitative

3.6 Data Analysis

Quantitative data were analyzed using descriptive statistical methods to examine changes in outcome attainment distributions across academic terms. Attainment was defined as the combined percentage of students rated at the Satisfactory or Exemplary levels relative to the program benchmark of 75 percent.

Analysis focused on comparing pre-intervention and post-intervention distributions across the four performance categories (Unsatisfactory, Developing, Satisfactory, and Exemplary). Because the data are aggregated at the program level and span multiple academic terms, interpretation emphasizes changes in distributions and stabilization patterns rather than inferential statistical testing or causal attribution.

3.7 Alignment with Continuous Improvement

Consistent with ABET's continuous improvement framework and the conceptual model illustrated in Figure 1, outcome assessment results were used to inform iterative refinement of instructional strategies within designated courses. Adjustments to rubric calibration, team structures, and ethics integration were implemented through routine program-level review processes. This study, therefore, examines how structured instructional refinements are associated with longitudinal patterns.

3.8 Methodological Scope and Ongoing Analysis

This study presents a longitudinal descriptive analysis of aggregated program-level outcome distributions within an ABET-aligned assessment framework. The design does not isolate individual-level treatment effects or establish causal relationships between instructional refinements and attainment changes. Continued longitudinal tracking across additional assessment cycles will be necessary to distinguish sustained stabilization from short-term cohort variability and to evaluate the durability of observed attainment patterns.

4. Results

This section presents longitudinal quantitative findings associated with structured instructional refinements targeting ABET Student Outcomes 5 (Teamwork) and 4 (Ethics and Professional Responsibility). Results are reported at the program level using aggregated assessment distributions. Consistent with the longitudinal descriptive design, findings are interpreted as longitudinal attainment patterns within an outcomes-based continuous improvement framework rather than as causal effects.

4.1 Student Outcome 5 (Teamwork) Attainment Trends

Figure 2 presents the longitudinal distribution of performance levels for ABET Student Outcome 5 (Teamwork) across assessed civil engineering courses from Fall 2021 through Spring 2024. Fall 2021 represents the primary pre-intervention baseline term. Outcome attainment is defined as the combined percentage of students rated Satisfactory or Exemplary relative to the program benchmark of 75%.

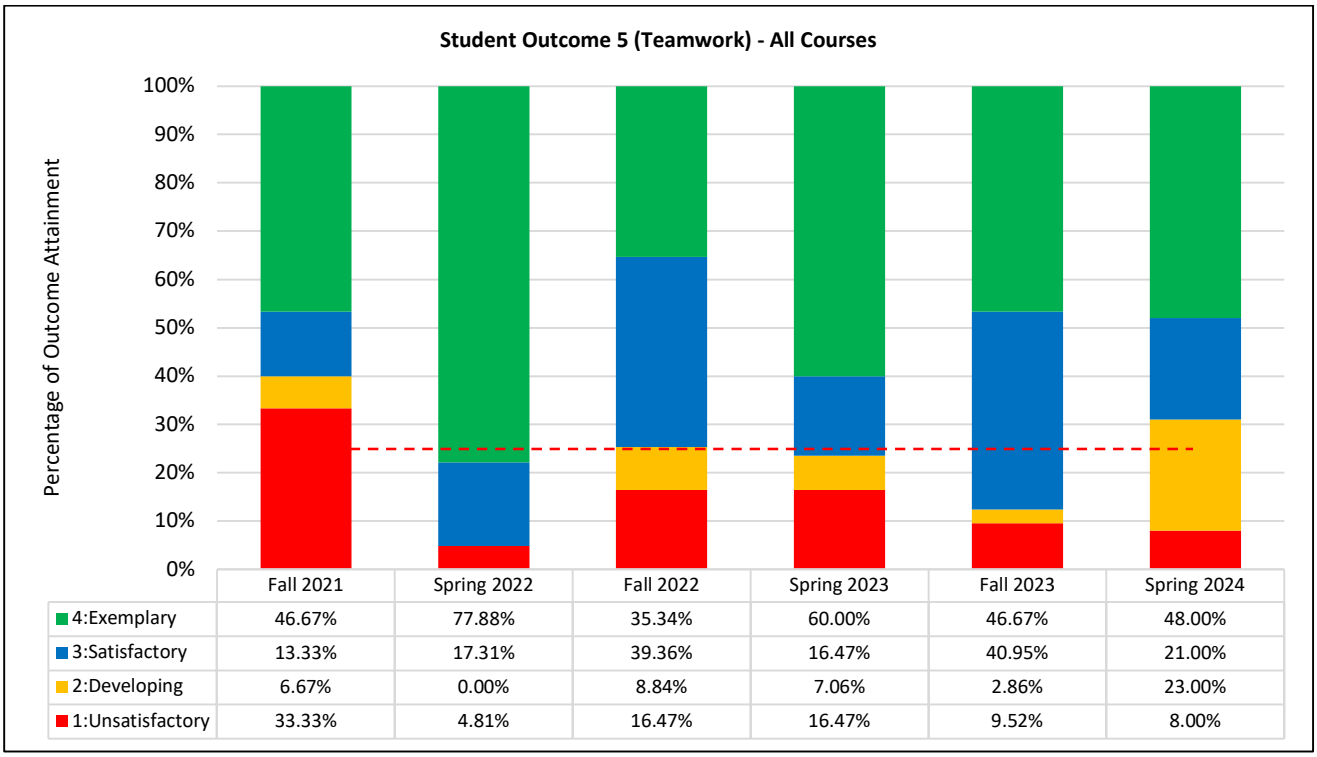
In Fall 2021, SO5 attainment was approximately 60%, falling below the benchmark. A substantial proportion of students were rated Unsatisfactory (33.33%), with remaining performance distributed across Developing and Satisfactory categories.

In Spring 2022, attainment increased to approximately 95%, driven by a high proportion of Exemplary ratings (77.88%) and minimal unsatisfactory performance. This term represents the initial post-baseline period following implementation of structured instructional refinements.

Attainment declined to 74.70% in Fall 2022, narrowly below the benchmark. However, subsequent terms demonstrated stabilization. From Spring 2023 through Fall 2023, attainment met or exceeded the 75% benchmark, supported by reductions in Unsatisfactory ratings and increased concentration within the Satisfactory and Exemplary categories.

In Spring 2024, an increase in the Developing category (23.00%) was observed, resulting in attainment levels slightly below the benchmark. This fluctuation reflects continued variability across cohorts and instructional contexts.

Across the full study period, the overall longitudinal pattern indicates movement from substantial unsatisfactory representation in the baseline term toward greater concentration of performance in higher attainment categories. Although term-to-term variability remains, the distributional shifts indicate increased concentration in higher attainment categories over time within the program. The pattern is characterized less by linear growth and more by progressive stabilization following initial fluctuation.



	Fall 2021	Spring 2022	Fall 2022	Spring 2023	Fall 2023	Spring 2024
4:Exemplary	46.67%	77.88%	35.34%	60.00%	46.67%	48.00%
3:Satisfactory	13.33%	17.31%	39.36%	16.47%	40.95%	21.00%
2:Developing	6.67%	0.00%	8.84%	7.06%	2.86%	23.00%
1:Unsatisfactory	33.33%	4.81%	16.47%	16.47%	9.52%	8.00%

Figure 2. Longitudinal distribution of program-level performance categories for ABET Student Outcome 5 (Teamwork) across academic terms (Fall 2021–Spring 2024). The figure shows changes in attainment distributions over time, including reductions in unsatisfactory performance and increased representation in the satisfactory and exemplary categories across successive assessment cycles.

4.2 Student Outcome 4 (Ethics and Professional Responsibility) Attainment Trends

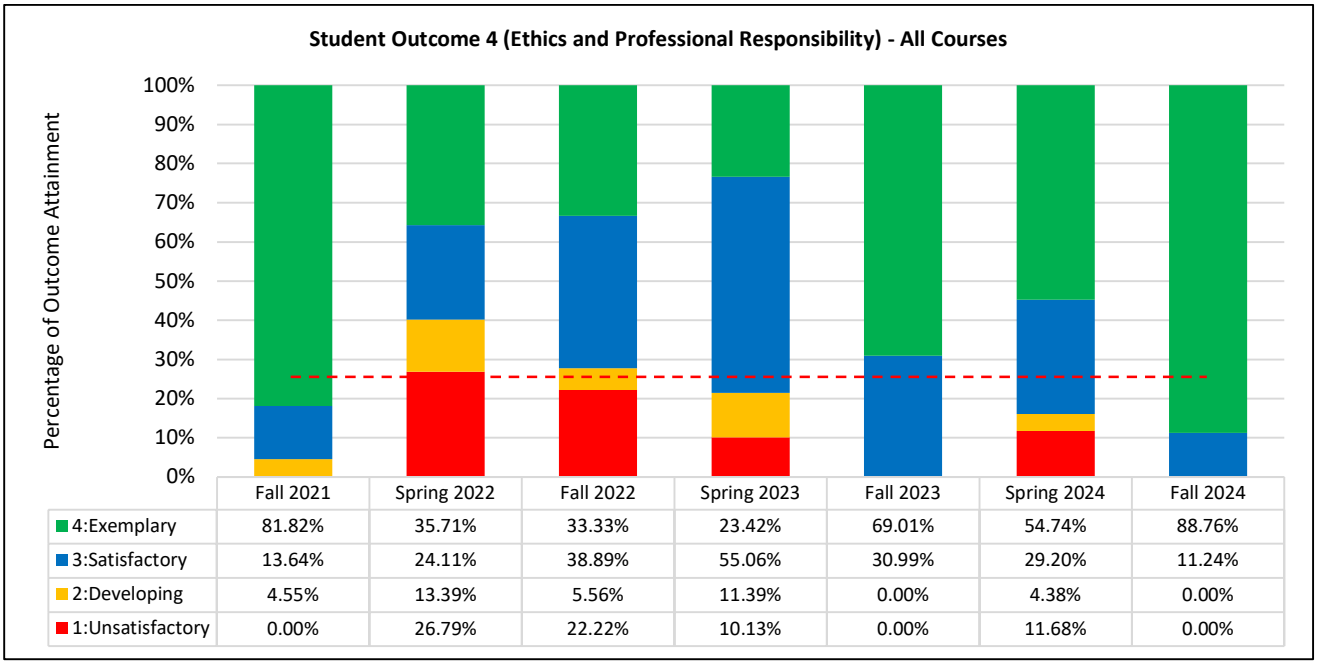
Figure 3 presents the longitudinal distribution of performance levels for ABET Student Outcome 4 (Ethics and Professional Responsibility) across assessed civil engineering courses from Fall 2021 through Fall 2024. Outcome attainment is defined as the combined percentage of students rated Satisfactory or Exemplary relative to the program benchmark of 75%.

In Fall 2021, SO4 attainment exceeded the benchmark, with more than 95% of students rated at the Satisfactory or Exemplary levels. In Spring 2022, attainment declined below the benchmark, with Unsatisfactory ratings increasing to 26.79%, representing the lowest attainment observed during the study period.

In subsequent terms, attainment patterns indicate gradual recovery. In Fall 2022 and Spring 2023, attainment approached the benchmark but did not consistently exceed it, reflecting continued variability across cohorts and course contexts. By Fall 2023, Unsatisfactory ratings were eliminated, and attainment exceeded the benchmark, supported by a substantial concentration of students in the Exemplary category.

The strongest performance is observed in Fall 2024, when Exemplary ratings reached 88.76% and overall attainment clearly exceeded the benchmark. Across post-decline terms, performance distributions show increased concentration in higher attainment categories and reduced representation in lower performance categories.

Overall, the longitudinal patterns indicate stabilization and strengthening of SO4 attainment across successive assessment cycles. Although variability across terms remains, the distributional shifts are consistent with increased concentration in higher attainment categories over time.



	Fall 2021	Spring 2022	Fall 2022	Spring 2023	Fall 2023	Spring 2024	Fall 2024
4:Exemplary	81.82%	35.71%	33.33%	23.42%	69.01%	54.74%	88.76%
3:Satisfactory	13.64%	24.11%	38.89%	55.06%	30.99%	29.20%	11.24%
2:Developing	4.55%	13.39%	5.56%	11.39%	0.00%	4.38%	0.00%
1:Unsatisfactory	0.00%	26.79%	22.22%	10.13%	0.00%	11.68%	0.00%

Figure 3. Longitudinal distribution of program-level performance categories for ABET Student Outcome 4 (Ethics and Professional Responsibility) across academic terms (Fall 2021–Fall 2024). The figure illustrates changes in outcome attainment distributions over time, including reductions in unsatisfactory performance and increased representation of satisfactory and exemplary ratings across successive assessment cycles.

4.3 Alignment with the Conceptual Framework

The observed attainment trends for Student Outcomes 4 and 5 are consistent with the conceptual framework presented in Figure 1, which illustrates relationships among assessment-identified performance gaps, theory-informed instructional refinements, and associated learning processes within a continuous improvement cycle. Reductions in unsatisfactory performance and increased concentration in the satisfactory and exemplary categories align with the types of collaborative engagement, role clarity, accountability, and reflective processes emphasized in the framework.

The results also reflect the iterative structure of ABET-aligned continuous improvement. Periods of fluctuation, particularly within the Developing performance category, coincided with ongoing adjustments to rubric calibration, team structuring practices, and ethics integration within designated courses. These patterns illustrate how outcome assessment data were incorporated into routine program-level review processes during the study period.

4.4 Study Limitations and Scope

The findings reported in this study are subject to several limitations that should be considered when interpreting the results. The analysis relies on descriptive comparisons of aggregated cohort-level data rather than controlled experimental or quasi-experimental designs. Accordingly, the results should not be interpreted as establishing causal relationships between instructional refinements and observed outcome attainment patterns.

The dataset spans a limited number of post-baseline assessment cycles. Additional longitudinal tracking will be necessary to determine whether the observed shifts in performance distributions reflect sustained stabilization rather than short-term cohort variability. Because the interventions were implemented within existing courses and across multiple instructors, variations in instructional emphasis, course context, cohort composition, and implementation fidelity may influence outcome attainment patterns across academic terms. Although rubric calibration and shared assessment instruments were used to promote consistency, differences in course delivery and learning environments may contribute to variability observed in certain assessment cycles.

The present analysis is quantitative in scope and focuses on program-level attainment distributions. Research Questions 1 and 2 are addressed directly through longitudinal descriptive comparison of SO5 (teamwork) and SO4 (ethical responsibility) distributions across pre-intervention and post-intervention terms. The study does not incorporate direct qualitative measures of student perception or instructional effectiveness.

Despite these limitations, the findings provide program-level evidence of directional movement toward higher attainment categories across successive assessment cycles. Continued longitudinal tracking, disaggregated course-level analysis, and complementary qualitative inquiry would strengthen interpretation of the durability, consistency, and broader applicability of observed attainment patterns.

Because outcome distributions are aggregated at the cohort level, observed attainment shifts may partially reflect cohort-specific characteristics rather than exclusively instructional refinement. It is possible that certain cohorts inherently demonstrate stronger or weaker teamwork or ethical competencies independent of curricular adjustments. Future analyses incorporating cohort tracking and course-level disaggregation would strengthen interpretation of intervention-associated patterns.

5. Discussion and Implications

The longitudinal results indicate progressive stabilization in attainment distributions for teamwork (SO5) and ethical responsibility (SO4) across successive assessment cycles. Reductions in sub-threshold performance and increased concentration within satisfactory and exemplary categories were observed in multiple post-baseline terms, indicating greater concentration of performance in higher attainment categories over time.

The observed distributional shifts align conceptually with the study's grounding in constructivist and experiential learning frameworks. Instructional refinements such as smaller team structures, rubric calibration, and integration of ethics discussions within technical assignments correspond to learning processes emphasized in these theoretical perspectives, including collaborative engagement, role clarity, accountability, and reflective reasoning. While the present analysis does not isolate the independent effects of specific interventions, the longitudinal trends suggest that structured instructional alignment within existing coursework may be associated with more stable professional competency attainment.

The findings also illustrate the practical utility of ABET-aligned assessment systems as mechanisms for instructional refinement. By examining longitudinal outcome distributions and identifying areas of variability, the program incorporated assessment results into routine curricular review processes. This approach reflects continuous improvement as an ongoing instructional design practice within an outcomes-based framework rather than solely as an accreditation requirement.

Although the findings are descriptive and context-specific, they offer insights for civil engineering programs seeking to strengthen professional competencies without expanding curricular requirements. The conceptual framework and structured instructional adjustments described in this study provide a model for integrating teamwork and ethics within technical coursework while maintaining alignment with established accreditation standards.

Continued longitudinal tracking across additional assessment cycles will be essential to distinguish sustained instructional impact from short-term cohort variability. Expanding the dataset to include additional pre-intervention baselines and extended post-intervention terms will enable clearer identification of trend durability and potential lag effects associated with structured instructional refinement.

6. Conclusion and Future Work

This study examined longitudinal program-level attainment patterns in ABET Student Outcomes 5 (Teamwork) and 4 (Ethics and Professional Responsibility) within an undergraduate civil engineering program. Using aggregated rubric-based assessment data collected across multiple academic terms, the analysis documented distributional shifts in outcome attainment across pre-intervention and post-intervention assessment cycles.

The results indicate directional movement toward higher attainment categories across successive terms, including reductions in unsatisfactory performance and increased concentration in satisfactory and exemplary ratings. Although the analysis does not establish causal relationships, the observed patterns suggest alignment between structured instructional refinements and stabilized professional competency attainment within an ABET-aligned continuous improvement framework.

The study highlights the importance of integrating professional outcomes within technical coursework and leveraging existing assessment systems to inform instructional refinement. By examining longitudinal

attainment distributions rather than single-cycle snapshots, the program operationalized continuous improvement as an ongoing, data-informed instructional process.

Future work will extend this analysis through additional longitudinal tracking and disaggregated course-level examination of attainment patterns. Expanded datasets will enable evaluation of durability, consistency, and cohort sensitivity in teamwork and ethics outcomes. Complementary qualitative inquiry may also provide deeper insight into the instructional mechanisms underlying observed distributional trends.

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