

Source details

International Symposium on Project Approaches in Engineering Education

Years currently covered by Scopus: from 2016 to 2025

Publisher: University of Minho

E-ISSN: 2183-1378

Subject area: [Social Sciences: Education](#) [Engineering: General Engineering](#)

Source type: Conference Proceeding

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Assessment Framework for Professional Competence Development in a Civil Engineering Integrated Design Project

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Abstract

Integrated Design Projects (IDPs) are widely used in civil engineering programmes to develop professional competencies; however, empirical evidence on the longitudinal robustness of outcome-based assessment frameworks remains limited. This study examines the stability and evaluative consistency of an assessment architecture implemented in a final-year IDP course across five consecutive cohorts (2018–2022), including periods affected by COVID-19–related disruption. Course Outcomes (COs), aligned with Programme Outcomes (POs), were assessed using multiple authentic instruments, including integrated design reports, oral presentations, and structured teamwork logs. Cohort-level attainment was analysed using one-way analysis of variance (ANOVA) to examine variation across academic cycles. Results indicate consistently high attainment across cohorts, with statistically significant differences ($p < 0.05$) but reduced variability during the disruption period. These findings suggest that a constructively aligned and authentically designed assessment architecture can provide stable and defensible evidence of professional competence across varying delivery conditions. While the results do not establish causal effects, they support the role of assessment design as a key contributor to outcome consistency in design-intensive engineering education.

Keywords: Authentic assessment design; Professional competence; Integrated Design Project; Outcome-based education; Civil engineering education; Engineering practice readiness.

1 Introduction

The civil engineering profession faces increasing expectations for graduates to enter practice with a balanced portfolio of technical mastery and professional competencies, including teamwork, ethical judgment, sustainability awareness, and project management. Global accreditation frameworks and professional bodies, including those aligned with Washington Accord signatories have identified a persistent gap between academic preparation and the multidisciplinary, constraint-driven realities of engineering practice. Consequently, outcome-based accreditation frameworks have been adopted worldwide to ensure engineering programmes demonstrate measurable attainment of graduate attributes (IEA 2021).

However, while programme-level outcome statements are well-established, a critical challenge remains: designing assessment systems that can reliably and authentically capture professional competence. Conventional assessment practices in many civil engineering programmes still prioritize analytical correctness and examination performance, offering limited evidence of a student's readiness to perform in complex professional roles. Integrated Design Project (IDP) courses have emerged as the primary curricular mechanism to address this gap, requiring students to synthesize knowledge across sub-disciplines in a collaborative environment. Despite their widespread use, empirical evidence linking IDP assessment design to sustained professional competence development across multiple cohorts and disruptive conditions remains limited. Many existing studies rely on single-cohort data or qualitative perceptions, which restricts the ability to evaluate the robustness and consistency of assessment frameworks. This study addresses this gap by examining how an integrated assessment architecture maintains stability and rigor across multiple academic cycles, including periods of extreme disruption.

From a theoretical perspective, the effectiveness of design-intensive courses such as Integrated Design Projects can be examined through the lens of constructive alignment and assessment validity. Constructive alignment posits that learning outcomes, teaching and learning activities, and assessment tasks must be coherently aligned so that students are systematically guided toward the intended forms of learning (Biggs & Tang, 2011). In this context, assessment plays a central role by signalling what constitutes valued learning and by shaping students' engagement with complex, authentic tasks. In outcome-based education, the validity of assessment systems extends beyond score reliability to include the extent to which assessment evidence meaningfully represents the intended professional competencies (Messick, 1995; Bloxham & Boyd, 2007). Contemporary validity arguments emphasise not only alignment and construct representation, but also consequential validity whether assessment practices lead to appropriate inferences about student capability and support defensible programme-level decisions (Kane, 2013).

In the context of engineering education, where professional competence involves integrated technical, cognitive, and interpersonal dimensions, assessment validity is closely linked to the authenticity of tasks and the consistency of evaluation across cohorts (Passow & Passow, 2017). Consequently, examining the longitudinal stability of outcome attainment provides an important *empirical* validity check on assessment architecture, particularly under conditions of instructional disruption. Framed within this theoretical lens, the present study evaluates whether a constructively aligned assessment architecture embedded in an Integrated Design Project can sustain valid and consistent measurement of professional competence over time.

This study addresses this gap by analysing longitudinal CO–PO attainment data across five academic cycles (2018–2022). Rather than attributing outcomes solely to instructional design, the study evaluates whether a constructively aligned assessment architecture can provide stable and interpretable evidence of professional competence under varying delivery conditions, including instructional disruption. Using one-way ANOVA, the study examines the consistency of outcome attainment and positions assessment design as a key structural element in outcome-based engineering education.

2 Course Context and CO-PO Framework

2.1 Course Context and Professional Orientation

The study was conducted within a final-year IDP course in an accredited civil engineering programme. Students undertook multidisciplinary projects integrating structural, geotechnical, transportation, water, environmental, and project management domains. Working in teams, they produced professional deliverables including design reports, presentations, and coordination records aligned with outcome-based accreditation requirements.

2.2 Course Outcomes and Programme Outcome Alignment

The pedagogical integrity of the IDP is maintained through eight Course Outcomes (COs) mapped to Programme Outcomes (POs) as defined by the Washington Accord and Engineering Accreditation Council (EAC). This alignment ensures that every assessment task generates evidence of graduate attributes required for professional licensure. Table 1 provides the mapping of CO-PO with EAC attributes and cluster MQF 2.0. The CO–PO mapping in Table 1 is aligned with the graduate attributes to ensure that assessment evidence generated within the IDP course contributes directly to programme-level accreditation, professional accountability, and continuous quality improvement (CQI). Each CO is assessed using multiple performance indicators embedded within authentic assessment tasks, allowing professional competencies to be observed, documented, and evaluated in an integrated manner rather than through isolated testing.

2.3 Role of CO–PO Mapping in Assessment and Accreditation

Importantly, the CO–PO mapping in this framework is not treated as a static compliance artefact, but as a functional design logic governing assessment evidence generation. Each mapping relationship informed the selection of assessment instruments, rubric criteria, and moderation processes, ensuring that evidence of professional competence was captured through authentic performance rather than isolated task completion. By embedding multiple performance indicators within a single integrated project, the framework enables holistic evaluation of graduate attributes while maintaining traceability to accreditation requirements. This design is particularly critical in capstone contexts, where professional competencies are inherently interdependent and cannot be meaningfully assessed in isolation.

Table 1. Alignment of Course Outcome (CO) with Accreditation-Based Competency Domains

Course Outcome (CO)	Programme Outcome (PO)	Accreditation-Aligned Competency Descriptor	Clusters MQF 2.0
CO1	PO3	WA3 – Ability to identify, formulate, and solve complex civil engineering problems through integrated design solutions that comply with applicable codes and standards (<i>EAC: Engineering Problem Solving; WA: Problem Analysis</i>)	C2 & C3A
CO2	PO5	WA5 – Ability to apply modern engineering tools, software, and techniques appropriate to civil engineering practice (<i>EAC: Modern Tool Usage; WA: Modern Tool Usage</i>)	C3D & C3E
CO3	PO6	WA6 – Understanding of professional responsibility, ethics, and regulatory requirements in engineering practice (<i>EAC: Engineer and Society; WA: Ethics</i>)	C5
CO4	PO7	WA7 – Ability to evaluate the environmental and sustainability impacts of engineering solutions in societal contexts (<i>EAC: Environment and Sustainability; WA: Sustainability</i>)	C5
CO5	PO9	WA10 – Ability to communicate effectively through professional technical reports and oral presentations (<i>EAC: Communication; WA: Communication</i>)	C3B & C3C
CO6	PO10	WA9 – Ability to function effectively as an individual, team member, or leader in multidisciplinary settings (<i>EAC: Individual and Team Work; WA: Teamwork</i>)	C3F
CO7	PO11	WA12 – Recognition of the need for independent learning and continuous professional development (<i>EAC: Lifelong Learning; WA: Lifelong Learning</i>)	C4A
CO8	PO12	WA 11 – Ability to apply project management and financial principles , including cost, constructability, and resource optimisation (<i>EAC: Project Management and Finance; WA: Project Management</i>)	C4B

3 Methodology

3.1 Study Context and Course Setting

The study was conducted within an IDP course offered in the final year of an accredited Bachelor of Civil Engineering programme at a public university in Malaysia. The course serves as a capstone-level professional preparation experience, requiring students to undertake a comprehensive civil engineering development project that integrates multiple disciplinary domains, including geotechnical engineering, structural engineering, transportation engineering, water resources, environmental engineering, and project management as presented in Figure 1. The IDP course was purposely designed to encourage critical thinking (CT) by providing the students with a very minimal information for initiating their thinking about the reasoning before further planning the design processes for developing solutions.



Figure 1. Six major areas in Civil Engineering

Students worked in multidisciplinary teams and were required to produce engineering deliverables consistent with professional practice, including integrated technical design documentation, formal oral presentations, and records of design coordination meetings. The course was explicitly structured to support outcome-based accreditation requirements, with clearly defined Course Outcomes (COs) mapped to Programme Outcomes (POs) aligned with professional competency domains (IEA, 2021).

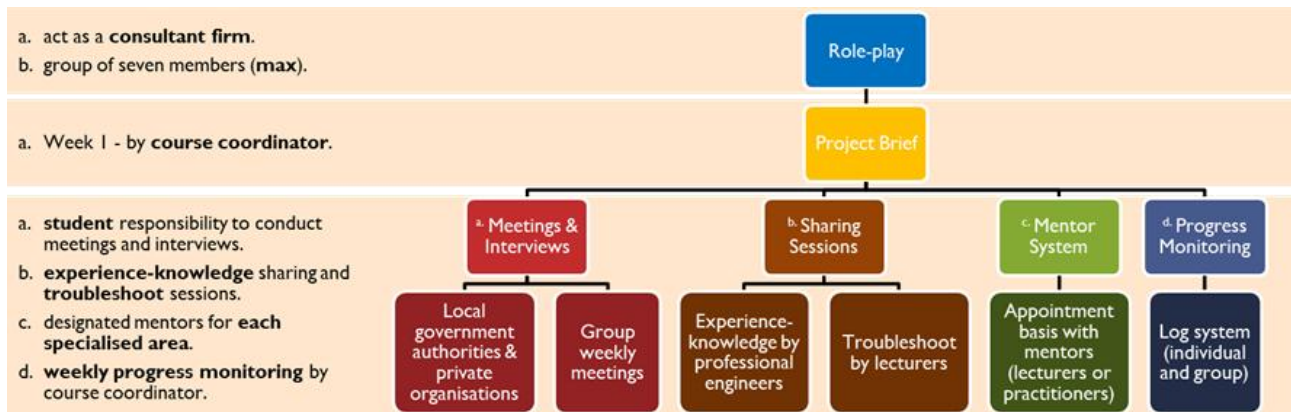


Figure 2. Details of the PdPc approach in IDP courses

A role-play approach was adopted, where student teams functioned as consultant firms. Each member assumed a discipline-specific role and developed solutions aligned with professional standards, supported by academic and industry consultation. This approach enabled authentic simulation of engineering practice under both face-to-face and online delivery conditions.

3.2 Assessment Framework Design

The assessment framework captures technical performance and professional competence through integrated reports, oral presentations, and structured logs. During the 2019/2020 session, the "Professional-Style Evaluation" was removed due to COVID-19, with its weight redistributed to the integrated report. Figure 3 shows the enhancement of IDP assessments. To determine framework stability, a One-Way ANOVA was performed, testing the null hypothesis that there was no significant difference in mean student attainment across pre-pandemic, disrupted, and post-pandemic cycles. Professional competence was assessed using four integrated instruments: (i) technical design reports, (ii) oral presentations, (iii) structured meeting logs, and (iv) professional-style technical evaluations (in selected sessions). These instruments collectively capture analytical rigor, communication, teamwork, and professional reasoning. Adjustments during COVID-19 involved redistributing technical evaluation weightage into report-based assessment.

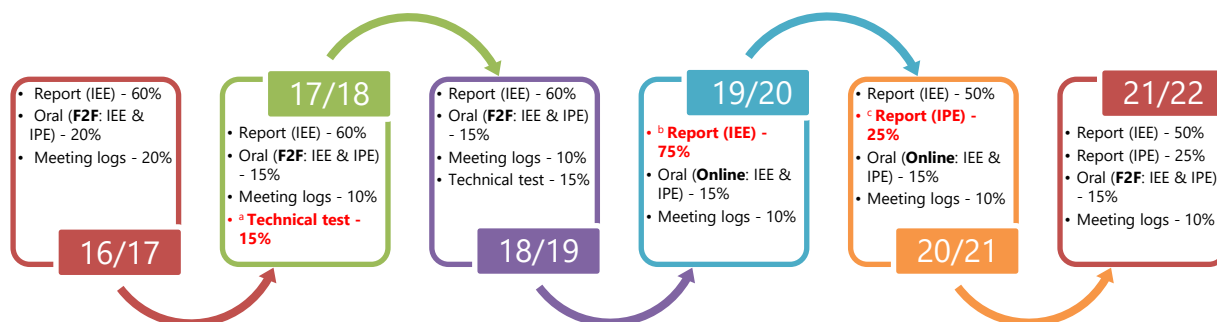


Figure 3. Evolution of IDP assessment structure

Note:

- ^a **Technical test was introduced in 2017/2018 session** to expose students with the essay writing assessment of the Professional Engineer (PE) examination. The weightage of oral presentation and meeting logs is 15% and 10%, respectively.
- ^b **Technical test was removed due to the COVID-19 pandemic in 2019/2020 session** to keep the confidentiality of the test questions. The technical test mark was embedded to report. The weightage of report evaluation by Internal Expert Evaluator (IEE) is 75%.
- ^c **Report assessment evaluated by Industry Panel Evaluator (IPE) was introduced in 2020/2021 session** to ensure the relevance of the outcomes to meet the industry demand. The involvement of industry is enhanced to not only in the evaluation of students' oral presentations. The weightage of report assessment between Internal Expert Evaluator (IEE) and Industry Panel Evaluator (IPE) is split into 50% and 25%, respectively.

This architecture evolved over the five-year study period (2018–2022) to enhance industry relevance. Notably, in the 2019/2020 session, the technical evaluation was removed due to COVID-19 pandemic constraints, with its weighting redistributed to the integrated report (75% total weighting). In 2020/2021, an Industry Panel Evaluator (IPE) was introduced to evaluate reports alongside internal experts, further aligning outcomes with industry demand.

It is important to note that the analysis does not aim to establish causal relationships between specific assessment components and student performance. Instead, the framework is evaluated as an integrated system, where multiple aligned instruments collectively contribute to the measurement of professional competence. This systems-level perspective aligns with contemporary validity arguments, which emphasise the interpretation and use of aggregated evidence rather than isolated assessment effects.

3.3 Data Collection and Outcome Mapping

Course Outcome attainment data were collected across five consecutive academic cycles (2018–2022) as tabulated in Table 2. Each dataset represented a complete student cohort and reflected final evaluated performance following internal moderation and programme-level quality assurance procedures. The longitudinal nature of the dataset enabled examination of both overall attainment levels and the consistency of professional competency development over time. During the 2019/2020 academic session, assessment delivery was modified in response to COVID-19-related constraints. Specifically, the professional-style technical evaluation component was removed, and its weighting redistributed within the internally evaluated integrated design report component. This adjustment provided an opportunity to examine the robustness of the assessment framework under disrupted delivery conditions.

Table 2. Course Outcome Attainment (% of Students Achieving Threshold) Across Academic Cycles

CO	PO	PO Descriptions	CO-Percentage				
			2018 (113)	2019 (114)	2020 (110)	2021 (107)	2022 (122)
CO1	PO3	Design/Development of solutions	97%	99%	99%	99%	100%
CO2	PO5	Modern Tools Usage	88%	96%	95%	96%	97%
CO3	PO6	The Engineer and Society	96%	100%	100%	100%	98%

CO4	PO7	Environment and Sustainability	79%	89%	94%	92%	86%
CO5	PO9	Communication	95%	98%	100%	99%	99%
CO6	PO10	Individual and Team Work	100%	99%	100%	100%	100%
CO7	PO11	Life Long Learning	65%	98%	94%	94%	94%
CO8	PO12	Project Management and Finance	80%	96%	98%	93%	96%

*Note: Attainment represents the percentage of students in each cohort achieving the predefined CO performance threshold following moderation. Cohort Year (Cohort Size).

3.4 Statistical Analysis

Descriptive statistics were first used to examine mean attainment levels and dispersion across academic cycles. To test for differences in mean CO attainment across cohorts, a one-way analysis of variance (ANOVA) was conducted, with academic year as the independent variable and mean cohort-level CO attainment as the dependent variable. The null hypothesis stated that there was no significant difference in mean CO attainment across academic cycles, despite changes in delivery mode and assessment weighting during the COVID-19 pandemic. To support interpretation of consistency, variance and coefficient of variation (CV) were examined across cohorts. Statistical significance was evaluated at the $\alpha = 0.05$ level. By calculating the F -statistic and p -value, the study moved beyond observing mean attainment to quantifying the degree of variation. This allows for a statistically grounded determination of whether the framework remained a reliable measure of professional competence during periods of external volatility.

While one-way ANOVA was employed to identify statistically significant differences in mean attainment across cohorts, interpretation of results was undertaken with caution. Statistical significance was not interpreted as evidence of instability, but rather as an indicator of expected cohort-level variation within a bounded and consistently high attainment range. To support interpretation of framework consistency, dispersion measures including variance and coefficient of variation were examined alongside mean trends. This combined analytical approach provides a more nuanced evaluation of assessment robustness than reliance on mean comparisons alone.

3.5 Validity, Reliability, and Quality Assurance

The study utilised anonymised programme-level attainment data generated through routine quality assurance processes and did not involve individual student identifiers. Several measures were implemented to enhance the credibility of the evaluation:

- Construct Validity was supported through explicit CO–PO mapping and alignment between assessment tasks and professional competencies.
- Assessment Reliability was reinforced through the use of standardised rubrics, multiple assessors, and moderation procedures conducted at programme level.
- Data Integrity was ensured by using officially recorded attainment data generated through the programme's quality assurance system.
- Professional Relevance was maintained by aligning assessment tasks with real-world engineering practices and accreditation requirements.

These measures collectively support the use of CO attainment data as a credible indicator of professional competence development within the IDP course.

4 Results and Discussion

4.1 Outcome Attainment and Assessment Interpretation

Across all cohorts, mean CO attainment exceeded programme benchmarks, indicating sustained professional competence development. Technical competencies (CO1, CO2) and professional skills (CO5, CO6) remained

consistently high, reflecting the effectiveness of integrated, role-based assessment tasks. However, cohort-level attainment represents aggregated performance and should be interpreted cautiously. While it indicates programme-level consistency, it does not capture individual learning trajectories or causal mechanisms. Therefore, observed stability reflects consistency in assessment outcomes rather than definitive evidence of improved learning effectiveness.

4.2 Assessment Architecture and Outcome Measurement Framework

This section integrates the assessment framework design, Course Outcome–Programme Outcome (CO–PO) mapping and outcome data generation, and the associated validity, reliability, and quality assurance processes into a single assessment architecture. These elements are treated as an interconnected system that governs how professional competence is elicited, measured, and interpreted through constructively aligned, authentic assessment tasks. Presenting them collectively clarifies how defensible outcome evidence is generated and sustained across multiple academic cycles, including periods of instructional disruption.

4.2.1 Development of Professional and Transversal Competencies

Beyond technical design proficiency, the results demonstrate meaningful attainment in broader professional and transversal competencies as shown in Table 2. Sustainability and environmental consideration (CO4) showed marked improvement, indicating increasing integration of environmental decision-making within design submissions. Similarly, project management and financial awareness (CO8) achieved strong attainment, reflecting the inclusion of cost estimation and constructability considerations within the integrated design report. Lifelong learning (CO7) initially exhibited greater variability but stabilised at a high attainment level in later sessions, indicative of students' increasing engagement with independent information sourcing and iterative problem-solving.

4.2.2 Impact of Assessment Restructuring during COVID-19

A key finding is the stability of CO attainment following assessment restructuring during the COVID-19 pandemic as shown in Table 2. The removal of a professional-style technical evaluation and redistribution of its weighting into the integrated report component did not result in measurable declines across any COs. This suggests that the assessment framework possessed inherent robustness, allowing professional competencies to be evaluated effectively even when delivery constraints required modification of assessment modes. Engineering work frequently occurs under changing constraints, and the ability to maintain performance standards despite process adjustments is a hallmark of professional competence.

4.2.3 Assessment Architecture as a Driver of Professional Competence Development and Assessment System Resilience

The assessment architecture contributed to consistent outcome measurement across cohorts. However, it cannot be concluded that the framework alone caused the observed stability, as other factors such as cohort variation and instructional practices may also influence outcomes.

4.3 Statistical Significance and Longitudinal Stability

The One-Way ANOVA revealed an F -value of 3.71, exceeding the critical value ($F_{crit} = 2.64$) at a significance level of $p < 0.05$ (calculated $p = 0.01$). This indicates that while attainment levels varied between cohorts, overall performance remained consistently high. The statistical analysis of the CO attainment data across five cycles (2018–2022) was presented in Table 3.

The data shows a consistent upward trajectory in student attainment averages, rising from a minimum of 87% in 2018 to a peak of 96% in 2022. This growth indicates that the integrated design project (IDP) successfully matured as a curricular mechanism for professional preparation, with peak performance in 2022 suggesting

that the return to post-pandemic norms combined with a refined assessment architecture enhanced students' ability to synthesize complex solutions.

Table 3. Synthesis of Longitudinal Attainment Trends (2018–2022)

Performance Dimension	Metric	Value	Interpretation
Growth Trend	Min/Max Average Attainment (%)	87 / 96	Sustained upward growth in professional readiness.
Systemic Stability	Min/Max Variance	147 / 7	Significant increase in assessment consistency during disruption.
Statistical Weight	ANOVA F -statistic	3.71	Significant variation across groups ($F > F_{crit}$ of 2.64).
Confidence Level	p -value	0.01	Highly significant result ($p < 0.05$).

Furthermore, a critical finding is the inverse relationship between academic disruption and assessment variance. In the initial 2018 cycle, the variance was at its highest (**147**), reflecting the expected fluctuations of a newly implemented system. Remarkably, during the COVID-19 pandemic in 2020, the variance reached its minimum of **7**, despite the removal of the professional-style technical evaluation. This sharp decrease demonstrates that the assessment framework became more **robust and predictable** under pressure. This suggests that the core deliverables (technical reports and logs) are highly resilient to external volatility. These results should be interpreted as evidence of controlled variability within a stable performance band, rather than as indicators of instability in the assessment system.

4.4 Implications for Engineering Practice

The findings have implications for engineering education and accreditation practice. The assessment framework provides a transferable model for evaluating professional competence, subject to enabling conditions such as clearly defined outcomes, constructively aligned tasks, calibrated rubrics, and systematic moderation. The observed stability in attainment and reduced variance supports the use of integrated assessment architectures as evidence for Continuous Quality Improvement (CQI) and accreditation compliance. From a professional perspective, the framework reflects real-world engineering conditions, where performance must be maintained under changing constraints.

5 Limitations and Future Work

In addition to contextual limitations, it is important to recognise that the use of aggregated cohort-level attainment restricts the ability to draw causal inferences about the effectiveness of specific assessment components. The analysis does not isolate the influence of individual instruments or pedagogical interventions, and therefore should be interpreted as a system-level evaluation rather than a controlled experimental study. This study is limited to a single institution and programme, which may constrain generalisability. In addition, CO attainment was evaluated using aggregated assessment data and did not include external performance indicators such as employer feedback or post-graduation outcomes. Future research could triangulate assessment data with industry evaluations, internship performance, or professional examination results to further validate the observed trends. Expanding the analysis to multiple institutions would also strengthen the evidence base for assessment architecture resilience.

6 Conclusion

This research examined the longitudinal performance of an outcome-based assessment architecture within a civil engineering Integrated Design Project (IDP). By analysing five years of Course Outcome (CO) attainment data, the study demonstrates that a strategically designed, industry-aligned assessment framework serves as a resilient mechanism for both professional formation and accreditation compliance. The findings confirm that authentic assessment tasks specifically multidisciplinary design reports, professional oral presentations, and structured coordination logs provide a reliable and stable measure of student readiness for engineering practice. The consistently high attainment across all COs indicates that these instruments successfully capture the synthesis of technical rigor and professional judgment required by the Washington Accord.

A primary contribution of this work is the empirical validation of assessment resilience. The One-Way ANOVA results ($F = 3.71, p < 0.05$) prove that the framework remained robust despite the significant delivery disruptions and assessment restructuring necessitated by the COVID-19 pandemic. Furthermore, the dramatic reduction in variance from 147 to 7 between 2018 and 2020 underscores the system's ability to provide consistent evaluative data even under external volatility. This characteristic mirrors the agility required in professional engineering environments, where performance standards must be maintained amidst changing project constraints.

Overall, this study demonstrates that a constructively aligned and authentically designed assessment architecture can provide stable and defensible evidence of professional competence across multiple cohorts and delivery conditions. While causal relationships cannot be definitively established, the longitudinal consistency observed supports the role of assessment design as a key structural element in outcome-based engineering education. By positioning assessment as an integrated architectural system rather than a procedural requirement, this work contributes both conceptually and practically to advancement of professional competence evaluation in engineering education.

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