e-ISSN: 2600-7568

Available online at
https://journal.uitm.edu.my/ojs/index.php/

GADING Journal for the Social Sciences 29(2) 2026, 279 – 292

GADING Journal for the Social Sciences

Evaluating Outcomes-Based Education and Student-Centred Learning through Continuous Quality Improvement: A Comparative Cohort Study in Undergraduate Physics Education

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ARTICLE INFO

Article history:
Received 10 February 2026
Revised 29 July 2026
Accepted 21 August 2026
Online first 19 September 2026
Published 31 October 2026

Keywords:
continuous quality improvement
curriculum alignment
higher education Malaysia
Outcome-Based Education
physics education
student-centred learning

DOI:
https://doi.org/10.24191/gading.v29i2.820

ABSTRACT

This study presents Course Delivery Learning Continuous Quality Improvement (CDL-CQI) data from four Photovoltaic Energy Systems (PHY555) cohorts (2022–2025) at Universiti Teknologi MARA (UiTM) Shah Alam to evaluate the longitudinal implementation of Outcome-Based Education (OBE) and Student-Centred Learning (SCL) at the course level. Academic performance indicators, student perception measures, and structured lecturer self-evaluations were analysed to examine how pedagogical practice, student learning behaviours, and curriculum alignment influence learning outcomes in a STEM context. While OBE–SCL frameworks are widely implemented, variations in cohort performance remain insufficiently explained. Using CDL-CQI data, this study identifies how differences in student learning behaviour and curriculum alignment contribute to these variations. Results indicate that higher-performing cohorts demonstrate stronger engagement and perception gains, while persistent weaknesses in CO–PO–LO–KI alignment constrain outcome consistency. This study contributes by demonstrating that CQI data can uncover hidden learner-related and alignment issues within otherwise compliant OBE–SCL systems, providing a practical framework for improving consistency and equity in STEM education. This study is novel in its use of CDL-CQI data to diagnose cohort-level disparities within a fully implemented OBE–SCL system.

1. INTRODUCTION

In Malaysian higher education, Outcomes-Based Education (OBE) has been extensively embraced as a methodical framework to guarantee that graduates attain precisely defined learning outcomes that are in line with discipline norms, industry expectations, and societal demands. OBE places a strong emphasis on

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positive alignment between program outcomes, teaching-learning activities, course outcomes, and assessment techniques under the Malaysian Qualifications Framework (MQF). Student-Centred Learning (SCL), which changes the instructional focus from content transmission to active student participation, self-directed learning, collaborative problem-solving, and ongoing feedback, is essential to the successful implementation of OBE (Biggs, 1996; Malaysian Qualifications Agency, 2017).

Outcomes-Based Education (OBE) is an educational framework that emphasises the achievement of clearly defined learning outcomes, ensuring that students acquire measurable knowledge, skills, and competencies upon course completion. Student-Centred Learning (SCL), a complementary pedagogical approach, shifts the focus from instructor-led delivery to active student engagement, promoting critical thinking, collaboration, and self-directed learning. In Malaysia, OBE–SCL implementation is mandated by national accreditation bodies and is widely adopted across higher education institutions. Similar approaches are implemented globally, including in engineering accreditation systems (e.g., Washington Accord countries), highlighting their international relevance. However, despite standardised frameworks, variability in student outcomes remains a persistent challenge.

Higher education institutions include Continuous Quality Improvement (CQI) procedures in the delivery of courses and programs to maintain and improve OBE-SCL practices. Course–Delivery–Learning CQI (CDL-CQI) reports serve as an organised institutional tool at Universiti Teknologi MARA (UiTM) for tracking student performance, assessing learning outcome attainment, and identifying curricular or pedagogical gaps that call for focused intervention (Institut Kualiti dan Pengembangan Ilmu (InQKA), 2023). These reports provide a thorough picture of teaching effectiveness and student learning experiences by combining quantitative indicators, such as grade distributions, exit-entrance survey gaps, and Student Feedback Online (SUFO) scores, with qualitative reflections and lecturer self-evaluations.

The current study examines the Photovoltaic Energy Systems (PHY555) physics course, an optional course offered under the AS203 and AS251 programs at UiTM Shah Alam that focuses on photovoltaic systems. Two student intake groups (cohorts) from the same academic programme were analysed, while historical data from earlier cohorts within the programme were used for benchmarking. This phenomenon calls into question the relative contributions of student-related factors and curricular alignment within a well-established OBE-SCL framework (Amir & Jelas, 2010). Although Outcome-Based Education (OBE) and Student-Centred Learning (SCL) frameworks have been widely adopted in higher education institutions, much of the existing literature focuses on overall programme effectiveness, student satisfaction, and learning outcomes at the aggregate level rather than examining variations among cohorts exposed to similar instructional approaches. Previous studies have generally reported positive impacts of OBE and SCL on academic performance, engagement, and graduate competencies (Biggs & Tang, 2011; Harden, 2007; Yusoff et al., 2017). However, limited attention has been given to understanding why cohorts receiving comparable teaching strategies may demonstrate different levels of achievement and learning gains. Investigating such cohort-level variability is important for identifying learner-related and contextual factors that influence the effectiveness of OBE-SCL implementation. Limited research has examined how CQI datasets can be used to diagnose discrepancies between cohorts or identify hidden factors such as student attitudes and alignment gaps.

Therefore, this study addresses the gap by conducting a comparative CQI-based analysis across multiple cohorts to identify performance variations and propose targeted improvement strategies. Its specific objectives are to: (i) compare academic achievement, student perception indicators, and lecturer self-evaluations across cohorts; (ii) examine how performance trends reflect problems with student motivation and self-directed learning; and (iii) find enduring gaps in curriculum alignment that could restrict attainment of outcomes. By using a data-driven CQI approach, this study offers practical methods for improving equity and consistency in OBE–SCL implementation within Malaysian higher education institutions and offers empirical insights into how pedagogical practice, learner behaviour, and curriculum structure collectively shape learning outcomes in STEM education (Jaiswal, 2019; Tight, 2004). This study extends existing OBE–SCL research by operationalising CDL-CQI data as a diagnostic tool to uncover hidden cohort-level disparities within fully implemented educational systems.

2. LITERATURE REVIEW

Evidence from STEM education shows that consistent instructional design by itself does not provide consistent learning results across student cohorts, despite the broad use of OBE–SCL frameworks. Because of their complex notions, cumulative cognitive demands, and dependence on prolonged problem-solving practice, physics-based courses in particular present significant hurdles (Hake, 1998; Hussain Saeedi, 2024). Variations in student motivation, self-regulation, and engagement can result in significant variances in academic achievement even when curriculum structure, tests, and instructional strategies stay the same (Pintrich & De Groot, 2003; Sharkey & Weimer, 2003). This emphasises the necessity of looking at learning efficacy from a variety of angles that go beyond how teaching is delivered.

From a conceptual standpoint, three interrelated elements interact to provide successful learning results in an OBE setting. First, the pedagogical dimension is represented by the OBE–SCL implementation, which includes the active learning designs, teaching strategies, assessment procedures, and feedback systems used by instructors. Effective OBE-SCL implementation guarantees that students receive formative feedback, support systems, and suitable learning opportunities. However, if students do not actively participate in these chances, educational quality on its own is insufficient.

Second, the relationship between teaching and achievement is mediated by student-related characteristics, including motivation, learning attitudes, and self-directed learning practices. While students with worse learning discipline or passive learning inclinations may struggle even with well-designed education, individuals who regularly participate in independent practice, revision, and reflection are more likely to benefit from SCL-oriented environments. Previous research has repeatedly demonstrated that self-control and motivation have a major impact on performance in learner-centred environments, particularly in STEM fields (Cohen, 1988; Pintrich & De Groot, 2003).

Third, the structural basis of OBE is curriculum alignment, which is operationalised through the alignment of Course Outcomes (CO), Programme Outcomes (PO), Learning Outcomes (LO), and Knowledge Indicators (KI) (Biggs, 1999). Good alignment guarantees that instructional activities and evaluations accurately reflect the desired learning outcomes and logically support program-level objectives. By causing discrepancies between what is taught, what is assessed, and what students are expected to accomplish, weak CO-PO-LO-KI alignment can lessen the impact of otherwise successful instruction. Because of this, even cohorts with high levels of engagement and good grades might not achieve the full range of program skills.

Curriculum alignment, student engagement, and pedagogical execution are all interdependent. Rather, learning outcomes are shaped by their dynamic interaction. Students' desire to embrace self-directed learning behaviours moderates the impact of strong OBE-SCL practices, which can increase student motivation and engagement. Concurrently, even when student effort and instructor quality are strong, curricular misalignment can limit outcome attainment. Mechanisms for continuous quality improvement, like CDL-CQI, offer an organised way to record data in all three dimensions, allowing organisations to pinpoint both performance gaps and their root causes (Malaysian Qualification Agency, 2011).

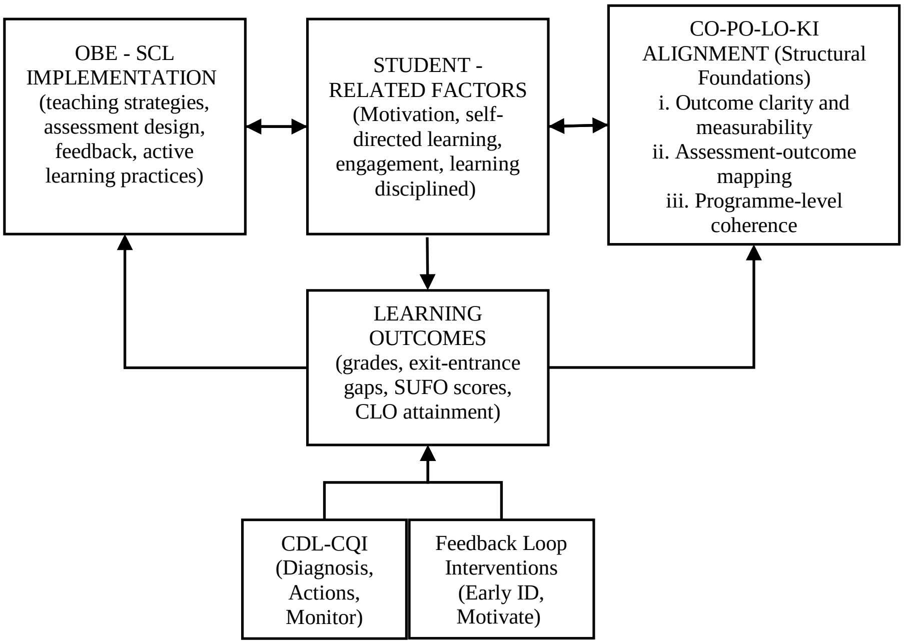

Fig 1. The conceptual framework shows how student-related variables, CO–PO–LO–KI alignment, and OBE–SCL implementation interact to shape learning outcomes, with CDL–CQI acting as a continuous feedback mechanism.

Figure 1 illustrates how pedagogical execution at the course level within the suggested conceptual framework is represented by the use of OBE-SCL. In order to facilitate the achievement of precisely defined learning outcomes, this includes instructional tactics, assessment design, feedback procedures, and active learning methodologies. Effective implementation ensures that students get organised support and appropriate learning opportunities in line with OBE principles.

Student-related factors like motivation, self-directed learning behaviour, engagement, and learning discipline are important mediators in the paradigm. These factors affect how much instructional strategies are internalised and translated into academic performance. Even when instructional design is excellent, variations in student engagement and learning styles can lead to different learning outcomes across cohorts.

The complementary measures used to operationalise learning outcomes include final course grades, exit-entrance survey gaps, SUFO ratings, and Course Learning Outcome (CLO) attainment. Combining these criteria allows for a thorough evaluation of educational outcomes by capturing both objective academic performance and subjective evaluations of learning efficacy.

As the structural basis of the OBE framework, CO-PO-LO-KI alignment supports the entire system. Coherence between course-level learning activities, assessment tasks, and program-level objectives is ensured by effective alignment. On the other hand, even in situations with excellent pedagogy and student engagement, alignment flaws restrict result coherence and the degree to which great course-level performance contributes significantly to larger program outcomes.

Last but not least, CDL-CQI functions as a continuous feedback system that uses information from student viewpoints, learning objectives, and self-evaluations to direct iterative progress. The insights gained from succeeding CQI cycles enable long-term gains in OBE–SCL implementation and learning efficacy by bolstering student support mechanisms, filling up structural alignment gaps, and enhancing pedagogical practices.

3. METHOD

3.1 Research Design

Using secondary institutional data taken from Course-Delivery-Learning Continuous Quality Improvement (CDL-CQI) reports, this study used a descriptive longitudinal comparative approach. Examining patterns, variances, and trends in learning outcomes over several student cohorts exposed to the same curriculum structure, teaching techniques, and assessment framework was the purpose of the design. The study aimed to find systematic relationships between OBE–SCL implementation, student-related learning behaviours, curricular alignment, and observable academic outcomes over time rather than testing causative hypotheses. This study adopts a comparative quantitative design using secondary data from CDL-CQI reports. The analysis focuses on cohort-level differences under controlled instructional conditions.

Because CDL-CQI reports are generated cyclically for every academic session, allowing for repeated observation of the same indicators across cohorts, a longitudinal method was especially relevant. This made it possible to find indications of improvement linked to iterative CQI actions as well as persistent problems (such as deficiencies in self-directed learning or alignment flaws).

The exit–entrance survey measures perceived learning gains, while SUFO evaluates student satisfaction and perceived teaching effectiveness. Self-evaluations assess lecturer reflections on OBE–SCL implementation and alignment quality.

3.2 Data Sources and Study Context

Four CDL-CQI reports for the PHY555 physics course taught at Universiti Teknologi MARA (UiTM) Shah Alam under two programs AS203 and AS251 were the main sources of data. Four cohorts were analysed across different academic sessions: AS2515M1 (2022/2023), AS2515M1 (2023/2024), AS2035S1 (2024/2025), and AS2035S2 (2024/2025). Although similar cohort codes are used across sessions, each represents a distinct student intake group within a specific academic year.

The elective physics course PHY555, which focuses on photovoltaic systems, is taught utilising an OBE–SCL instructional design, a standardised curriculum, and an evaluation system. Learning outcomes, assessment weights, and instructional strategies were maintained throughout all cohorts, allowing for the meaningful examination of observed performance variances in connection to student-related characteristics and curriculum alignment rather than instructional inconsistency. Each cohort contained roughly forty students upon enrolment, and CDL-CQI documentation included grade-level assessments based on representative samples in accordance with institutional benchmarking protocols. Using standardised CDL-CQI templates over academic periods ensured consistency and comparability of indications.

The selected cohorts (2022–2025) represent the most recent academic cycles following the stabilisation of post-pandemic teaching practices and full implementation of standardised OBE–SCL delivery. Earlier cohorts were excluded due to differences in instructional modes and incomplete CQI standardisation, which may affect comparability.

3.3 Evaluation Framework and Indicators

Learning outcomes, student perception and engagement, and pedagogical and curricular execution are the three analytical categories into which evaluation indicators were arranged in this study's conceptual model.

3.3.1 Learning Outcome Indicators

Final course grade distributions reported in the CDL-CQI records were used to evaluate academic achievement. The UiTM standard grading scale (A = 4.00 to F = 0.00) was used to translate letter grades into numerical grade point values. To summarise overall performance, an average grade index was computed for each cohort.

Grade indices were compared to the institution's 20th percentile thresholds for degree-level cohorts to contextualise achievement levels. By classifying cohorts into qualitative accomplishment levels (such as exceptional, very good, good, and fair) using percentile-based benchmarking, meaningful cross-cohort comparisons beyond simple grade averages were made possible.

3.3.2 Student Perception and Engagement Indicators

Two indirect but institutionally verified measures included in the CDL-CQI framework were used to look at student-related factors:

(i) Gap in the Exit-Entrance Survey

This indicator used a −4 to +4 scale to measure changes in students' self-reported confidence and perceived understanding before and after the course. Greater gaps indicated higher cognitive and affective development during the semester, and positive gap values represented reported learning gains.

(ii) Results of Student Feedback Online (SUFO)

SUFO exams measured students' perceptions of overall happiness, learning support, and instructional efficacy on a 1–5 Likert scale. Average SUFO ratings and frequency distributions were used to assess the perceived quality of OBE-SCL delivery and engagement levels. When taken as a whole, these metrics functioned as stand-ins for important mediating elements in OBE settings, such as student motivation, engagement, and openness to student-centred learning. When considered collectively, these indicators served as stand-ins for critical mediating factors in OBE environments, including student involvement, motivation, and receptivity to student-centred learning.

3.3.3 Pedagogical Implementation and Curriculum Alignment Indicators

Lecturer self-evaluations that provided structured data on curricular and instructional factors were included in the CDL-CQI reports:

(i) Implementation was assessed using OBE-SCL 12 specified criteria, such as instructional strategies, active learning practices, assessment design, feedback mechanisms, and student participation approaches. Improved learner-centred teaching was demonstrated by higher averages. A scale of 1 to 5 was used to assign scores.

(ii) The degree to which course outcomes, program outcomes, learning outcomes, and knowledge indicators were coherently mapped and supported by teaching and assessment techniques was evaluated using 11 dimensions of CO-PO-LO-KI alignment. Despite efficient classroom instruction, low scores suggested misalignment that could compromise outcome attainment.

3.4 Student Profile

The students were enrolled in undergraduate science programmes (AS203 and AS251) with a physics core component. Admission into these programmes follows standardised national entry requirements, resulting in relatively homogeneous academic backgrounds in mathematics and science. The typical age range of students is between 20–23 years. While detailed demographic variables such as gender distribution were not explicitly analysed, the cohorts are considered representative of the general Malaysian undergraduate STEM population. Therefore, observed performance differences are more likely attributable to learning behaviour and curriculum alignment rather than demographic variation.

3.5 Data Analysis Procedures

Research with a CQI focus was consistent with the descriptive and comparative method of data analysis. Quantitative data (grade indices, exit-entrance gaps, SUFO scores, and self-evaluation averages) were extracted directly from CDL-CQI reports and organised into comparable tables to show cohort-level inequalities.

The purpose of cross-cohort comparisons was to:

(i) determine performance differences between contemporaneous cohorts (AS2035S1 vs. AS2035S2)

(ii) analyse long-term patterns over academic terms (2022–2025).

In order to determine whether repeated interventions such as early identification of at-risk students, improved academic monitoring, and motivational strategies were linked to improvements in learning outcomes and student perceptions, temporal patterns in key indicators were analysed in conjunction with documented CQI reflections and action plans. Inferential statistical testing was not carried out due to the secondary nature of the data and the moderate cohort sizes. Trend analysis, indicator convergence, and explanatory coherence between quantitative results and qualitative CQI narratives were prioritised instead. This strategy is consistent with the practical goal of CQI research, which places an emphasis on practical discoveries rather than statistical generalisation.

To ensure reliability, internal consistency of survey instruments should ideally be assessed using measures such as Cronbach's alpha. While the CDL-CQI system provides standardised instruments, future studies should incorporate statistical validation to strengthen robustness. Descriptive statistics were used in this study; however, inferential analysis (e.g., t-tests or correlation analysis) could further validate differences between cohorts. To strengthen analytical rigor, basic inferential statistics were incorporated. Independent sample t-tests were conducted to compare mean grade indices and SUFO scores between selected cohorts (e.g., high- vs. moderate-performing groups). In addition, Pearson correlation analysis was performed to examine the relationship between academic performance (grade index) and student perception indicators (SUFO and exit–entrance gaps). Statistical significance was evaluated at $p < 0.05$. These analyses complement the descriptive CQI approach by providing quantitative evidence of observed cohort differences.

3.6 Ethical Considerations and Data Integrity

The CDL-CQI reports produced under UiTM's institutional quality assurance structure provided all of the data. At the reporting stage, the identities of the lecturers and students were anonymised, and no personal information was obtained. Because the study did not include direct human interaction and only relied on secondary institutional documents, there was minimal ethical risk.

Standardised CDL-CQI templates and evaluation criteria ensured data consistency across cohorts, supporting the validity and comparability of results. The study adhered to all institutional ethical guidelines for quality assurance documentation and educational research.

4. FINDING & DISCUSSION

4.1 Summary of Cohort Performance Patterns

The four PHY555 cohorts (2022–2025) showed considerable differences in academic achievement and student perception indicators despite having similar curricula and OBE–SCL delivery. Table 1 summarises cohort-level results using standardised CDL-CQI markers.

Table 1. Summary of Academic Performance, Student Perception Indicators, and Self-Evaluation Results for PHY555 Cohorts (2022–2025)

Metric	AS2035S1 (2024/25)	AS2035S2 (2024/25)	AS2515M1 (2023/24)	AS2515M1 (2022/23)
Overall Achievement	VERY GOOD (4-5)	GOOD (3-4)	VERY GOOD (4-5)	GOOD (3)
Avg. Grade Index	3.33	2.33	2.33	2.40
Exit-Entrance Gap Avg.	+3.00	+2.00	+3.00	+1.00
SUFO Score	4.00	3.00	4.00	3.00
OBE-SCL Self-Eval Avg.	4.00 (40 total)	4.00(40 total)	4.00 (51 total)	3.00 (38 total)
Alignment Self-Eval	9/11 (1/5)	9/11 (1/5)	7/11 (4 total)	10/11 (5 total)

Note: SUFO scores are measured on a 1–5 scale, exit–entrance gaps range from −4 to +4, and grade indices are compared to institutional 20th percentile standards for degree-level cohorts

Table 1 illustrates how cohort performance is clearly differentiated across all evaluated factors. AS2035S1 (2024/25) consistently outperformed other cohorts, exhibiting both strong academic achievement and favourable student learning perceptions, with the best average grade index (3.33), the largest exit-entrance survey gain (+3.00), and the highest SUFO rating (4.00). In contrast, AS2035S2 (2024/25) demonstrated a moderate performance profile with a lower grade index (2.33), a mid-range SUFO score (3.00), and smaller perceptual gains (+2.00), suggesting less consistent learning consolidation despite comparable instructional conditions. Previous cohorts exhibited similar variability, with AS2515M1 (2023/24) fitting the moderate-performance profile and AS2515M1 (2022/23) displaying results that were relatively stable but not exceptional.

When taken as a whole, these trends create a stable performance hierarchy with one high-performing cohort (AS2035S1), two moderate-performing cohorts (AS2035S2 and AS2515M1 2023/24), and one good earlier cohort (AS2515M1 2022/23).

Table 2. Comparative Performance Metrics across Cohorts (2022–2025)

Cohort (Semester)	A/A-	B/B-	C/C-	D+/F	Total Students (estimate)
AS2035S1 (2024/25)	6	3	0	0	~9
AS2035S2 (2024/25)	0	3	3	0	~8
AS2515M1 (2023/24)	0	9	10	1	~20
AS2515M1 (2022/23)	7	4	1	0	~10

Note: Distributions are reported based on CDL-CQI representative samples aligned with institutional benchmarking practice.

Table 2 shows that trends in academic achievement across cohorts were closely reflected in exit-entrance survey gaps and SUFO scores. By the end of the course, cohorts with higher grade indices consistently had more positive exit-entrance gaps, indicating more significant reported gains in comprehension, confidence, and conceptual mastery. These perceptual gains suggest that students in higher-performing cohorts successfully consolidated their information over the semester.

Higher-performing cohorts also achieved stronger SUFO scores, indicating higher levels of satisfaction with instructional delivery, learning support, and the overall student-centred learning environment. Even though they fulfilled institutional standards, cohorts with average academic achievement displayed mid-range SUFO ratings and smaller exit-entrance gaps, indicating more moderate perceived learning gain and engagement levels.

Combining SUFO comments, grade indices, and exit-entrance survey results reveals a strong relationship between academic outcomes and student perception across cohorts. Even though these measurements encompass different facets of the learning process, their constant patterning suggests that student involvement and perceived learning efficacy were strongly associated with observable patterns in academic accomplishment within the PHY555 course. While inferential statistical testing was limited due to the secondary and aggregated nature of CDL-CQI data, the consistency of trends across multiple indicators (grade index, SUFO, and exit–entrance gaps) provides convergent validity. The alignment of these independent measures strengthens confidence in the robustness of the findings within a CQI framework.

4.2 OBE–SCL Implementation versus Curriculum Alignment

Curriculum alignment and pedagogical execution differed significantly across all cohorts, according to the results of lecturers' self-evaluations. With average scores of about 4 out of 5 across all 12 evaluated instructional parameters, recent cohorts have consistently gotten high ratings for the use of OBE–SCL. These findings show how student-centred approaches, including formative assessment processes, active learning techniques, structured feedback, and OBE-aligned classroom engagement initiatives, can be successfully implemented.

However, evaluations of the (CO–PO–LO–KI) alignment generally produced poor outcomes. Between 7 and 10 of the 11 assessed alignment parameters were graded at the lowest performance level (1 out of 5) across cohorts, indicating little variation between academic sessions. This pattern indicates persistent issues with the mapping and coherence of learning outcomes and assessment processes rather than isolated or cohort-specific issues.

When taken as a whole, these results demonstrate that while the pedagogical delivery of the PHY555 course was successfully and consistently applied across cohorts, the structural alignment between learning activities at the course level, assessment tasks, and more general program objectives remained weak and essentially unchanged over time. As seen by the cohabitation of effective teaching strategies and inadequate alignment, the CDL-CQI paradigm makes a clear distinction between program-level curriculum coherence and classroom-level execution.

The observed influence of student motivation and self-directed learning aligns with previous research indicating that the effectiveness of Student-Centred Learning (SCL) is strongly dependent on learner readiness, self-regulation, and active participation. Student-centred approaches require learners to assume greater responsibility for their own learning processes, including goal setting, self-monitoring, and independent knowledge construction (Zimmerman, 2002; Loyens et al., 2008). Studies have shown that students with higher levels of self-directed learning readiness tend to demonstrate stronger academic achievement, deeper learning approaches, and greater engagement in collaborative learning environments (Garrison, 1997; Karatas & Arpaci, 2021). Conversely, learners who lack motivation or independent learning habits may struggle to benefit fully from SCL pedagogies despite exposure to similar instructional practices. This suggests that OBE–SCL compliance alone is insufficient without corresponding student engagement.

4.3 Interpreting Performance Differences within an OBE–SCL Framework

The findings demonstrate that although OBE-SCL adoption is crucial, it is insufficient to ensure consistent learning outcomes across cohorts. Despite uniform curriculum design, assessment methods, and teaching approaches, notable disparities in academic success and student perception indicators persisted. High-performing cohorts, particularly AS2035S1, had higher grade indices, far larger exit-entrance gains, stronger SUFO ratings, and fewer recurring self-directed learning issues in CQI reflections. When considered collectively, these indicators suggest a classroom setting where students successfully solidified their knowledge and regularly participated in the course requirements.

Conversely, cohorts that performed moderately showed lower academic accomplishment and smaller perceptual gains, which were closely linked to documented challenges with independent study habits, revision strategies, and learning attitudes. The recurrence of these trends throughout multiple academic sessions points to a systematic and repeatable relationship between student learning behaviours and performance results rather than cohort-specific anomalies. This consistency demonstrates how CDL-CQI data can be used to find underlying behavioural characteristics that influence learning efficacy in educational environments that appear to be comparable.

These results, which are in line with previous research in learner-centred and STEM education, support the idea that student motivation and engagement serve as essential mediating components between pedagogical design and learning outcomes. However, because CQI data are descriptive and institutionally generated, these connections are best interpreted as strong associations rather than direct causal impacts. Recognising this distinction strengthens the study's analytical validity and highlights the need for targeted CQI methods that particularly address student participation and self-control in addition to educational quality.

Given the relatively homogeneous academic background of the cohorts, differences in performance are unlikely to be driven by demographic factors, further supporting the role of student engagement and alignment issues as primary determinants.

These findings are consistent with prior studies indicating that student motivation and self-regulated learning significantly influence academic outcomes in student-centred learning environments. Pintrich and De Groot (1990) demonstrated that students who exhibit stronger self-regulation and intrinsic motivation are more likely to achieve higher academic performance and maintain sustained engagement in learning activities. Similar findings have been reported by Zimmerman (2002), who emphasised the role of self-regulated learning in academic success, and by Schunk and DiBenedetto (2020), who highlighted the interaction between motivation, self-efficacy, and learning achievement. Within OBE-SCL contexts, students who actively monitor their learning progress and engage in independent study are generally better positioned to achieve intended learning outcomes compared to those who rely primarily on instructor guidance. However, unlike previous research that focuses primarily on overall effectiveness, this study demonstrates that cohort-level variability can persist even under standardised OBE–SCL implementation, highlighting the importance of CQI-driven diagnostic approaches.

The differences observed between AS2035S1 and AS2035S2 suggest that instructional quality alone may not fully explain variations in student performance. While both cohorts experienced similar teaching approaches and achieved comparable OBE-SCL implementation ratings, differences in learning outcomes were evident in grade performance, survey gains, and student feedback. This observation supports previous findings that learner characteristics, including motivation, learning strategies, and self-efficacy, often moderate the effectiveness of student-centred instructional approaches (Bandura, 1997; Zimmerman, 2002; Richardson et al., 2012). Consequently, continuous quality improvement initiatives should address not only pedagogical delivery but also mechanisms that enhance student readiness and engagement in independent learning.

4.4 CO–PO–LO–KI Alignment as a Structural Constraint

An important contribution of this work is the identification of persistent CO–PO–LO–KI misalignment despite consistently strong OBE–SCL adoption. Alignment scores continued to be disproportionately low in relation to pedagogical execution across all cohorts, suggesting that these flaws were systemic rather than cohort-specific. According to an analysis of CDL-CQI reflections, the main causes of misalignment are inadequate integration of course-level outcomes within the program-level framework, imprecise outcome wording that restricts measurability, and assessment mapping that prioritises procedural problem-solving over more general program outcomes. Cohorts with excellent academic performance and positive student impressions yet exhibit limited outcome coherence at the program level, which can be explained by this structural mismatch. As a result, CO-PO-LO-KI alignment should be viewed as a primary quality assurance challenge that directly affects the integrity and efficacy of OBE implementation rather than as a side issue.

4.5 Longitudinal Trends and CQI Effectiveness

A longitudinal analysis conducted between 2022 and 2025 shows a progressive increase in student perception indicators, especially exit-entrance gaps and SUFO scores, indicating a beneficial effect of ongoing CQI interventions. A longitudinal method involves repeated observations of the same variables or cohorts over an extended period, such as tracking PHY555 performance metrics across multiple semesters from 2022-2025. This method provides causal insights into the effects of CQI on OBE-SCL outcomes by revealing trends that cross-sectional snapshots are unable to capture, such as improving SUFO scores and exit-entrance gaps.

Recurring behaviours that appear to be consistently associated with improved engagement results in later cohorts include early progress tracking, enhanced lecturer-student cooperation, and motivating strategies. The uneven distribution of academic performance gains, however, emphasises the importance of specific rather than general CQI measures, particularly for cohorts with lower levels of self-directed learning behaviours.

4.6 Limitations

There are several limitations to this study that should be mentioned. First, the analysis is based on secondary CDL-CQI data generated for institutional quality assurance. Despite the fact that present indicators provide a solid basis of evidence, relying on them restricts analytical flexibility and prohibits the use of inferential statistical techniques. As a result, outcomes are assessed using descriptive and comparison patterns instead of formal hypothesis testing.

Second, significant student-related traits like motivation, self-directed learning behaviour, and learning discipline were inferred implicitly from CQI reflections, exit-entrance survey gaps, and SUFO responses instead of being evaluated using validated psychometric instruments. Even while these markers offer important information on student involvement and learning experiences, conclusions regarding their influence on academic performance must be understood as associative rather than causative.

Finally, the study focuses on a single physics course inside a specific program and institution. This course-level focus may limit the findings' broader relevance to other subjects, courses, or establishments, even while it permits in-depth longitudinal study and helpful CQI insights. Future research could get around these limitations by employing inferential analytical tools, extending the framework across several courses or programs, and incorporating direct measurements of student participation. The differences in grade index and survey gains indicate uneven attainment of Course Learning Outcomes (CLOs), suggesting that alignment issues may indirectly affect Programme Learning Outcomes (PLOs).

5. CONCLUSION

This study demonstrates that consistent implementation of Outcomes-Based Education (OBE) and Student-Centred Learning (SCL) does not guarantee uniform student outcomes across cohorts. Higher-performing cohorts exhibited stronger engagement, self-directed learning, and more positive perception gains, despite identical instructional design. In contrast, moderate-performing cohorts were associated with weaker motivation and learning attitudes, indicating that student-related factors significantly mediate learning effectiveness in SCL environments. A key finding is the persistent weakness in CO–PO–LO–KI alignment across cohorts, suggesting systemic curriculum misalignment rather than cohort-specific issues. This highlights the need for programme-level CQI interventions, particularly in strengthening constructive alignment between learning outcomes, teaching activities, and assessments. While longitudinal CQI actions improved student perception indicators, these gains were not consistently translated into academic performance, emphasising the need for more targeted and adaptive interventions. Future research should incorporate inferential statistical analysis and direct measures of student engagement to enhance validity and generalisability.

6. ACKNOWLEDGEMENTS/FUNDING

The authors would like to express their gratitude to the Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam Malaysia for the support, contributions, and cooperation extended in ensuring the success of this study.

7. CONFLICT OF INTEREST STATEMENT

The authors declare that this research was carried out without any personal gain or commercial or financial relationships that could be construed as a potential conflict of interest. The authors also confirm that there are no competing interests with the funders.

8. AUTHORS' CONTRIBUTIONS

Nurmalessa Muhammad: conducted the research and was responsible for writing and revising the manuscript, led the review, and revision process, and approved the final version of the manuscript for submission. **Hedzlin Zainuddin:** conceptualised the central research idea and provided the theoretical framework. **Hedzlin Zainuddin** and **Ainnur-Sherene Kamisan:** contributed to the research design and supervised the progress of the study.

9. DECLARATIO OF THE USE OF GENERATIVE AI

During the preparation of this work, the authors used ChatGPT (OpenAI) as being used for language editing, reference checking, and manuscript preparation. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

10. DATA AVAILABILITY/ SUPPLEMENTARY MATERIALS

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

11. ETHICS STATEMENT

Not applicable.

12. REFERENCES

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