Journal of Curriculum Studies Research

https://curriculumstudies.org
E-ISSN: 2690-2788
Volume: 7 Issue: 2 2025
pp. 53-72

Toward Precision on Evaluation: Hierarchical Weighting-Based Assessment on Implementation of Outcome-Based Curriculum

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Article Info
Received: December 23, 2024
Accepted: May 20, 2025
Published: August 10, 2025

10.46303/jcsr.2025.11

How to cite
Roza, Y., Id, I. D., Andriyani, Y., Kurniawan, R., Adnan, A. (2025). Toward Precision on Evaluation: Hierarchical Weighting-Based Assessment on Implementation of Outcome-Based Curriculum. *Journal of Curriculum Studies Research*, 7(2), 53-72.
https://doi.org/10.46303/jcsr.2025.11

ABSTRACT

Assessing learning outcomes is essential for measuring student achievement and enhancing educational effectiveness. However, traditional assessment methods often struggle to capture the complexity of diverse competencies, leading to gaps in evaluation and improvement. Outcome-based education (OBE) represents a shift from conventional paradigms by emphasizing the attainment of predefined learning objectives at multiple levels, including student, course, and program outcomes. This study introduces a hierarchical weighting-based assessment framework designed to evaluate learning outcomes comprehensively. The framework employs a three-tier weighting system that assigns differentiated weights to various assessment elements. Using a development research model, this approach enables a nuanced and holistic evaluation of student performance. The methodology involved needs analysis, assessment modeling, practical implementation of the framework, and case study analysis to demonstrate its effectiveness. The User Experience Questionnaire (UEQ) was administered to 225 users to evaluate the system's usability and emotional impact. Results show that the proposed framework offers a more accurate representation of student achievement, aligning closely with intended learning outcomes and performance indicators, and effectively distinguishing varied competencies across diverse assessments. The findings highlight its potential scalability across educational institutions seeking to refine assessment practices. Additionally, this framework presents a promising strategy to enhance the precision, inclusivity, and engagement of educational evaluation systems.

KEYWORDS

Assessment method; evaluation; weighting-based assessment; learning outcomes; outcome-based curriculum.

INTRODUCTION

Assessment is an integral component of the educational process, enabling the evaluation of learning objectives, understanding of student needs, and delivery of constructive feedback. Through assessment, educators can identify students' strengths and weaknesses, adjust instructional strategies accordingly, and ensure that each learner has the opportunity to reach their full potential. This comprehensive approach encompasses not only the evaluation of final outcomes but also ongoing formative assessments that support the entire learning experience (Tungpalan & Antalan, 2021).

The curriculum plays a critical role in shaping students' development. Consequently, educational institutions should assign students to specialized curricular tracks that align with their intellectual abilities and future aspirations (Adams, 2019). Outcome-based education (OBE) has emerged as a leading pedagogical framework, designed to align educational practices with the achievement of specific learning outcomes. Its implementation centers on organizing all elements of the educational system around the competencies students are expected to demonstrate upon completing their learning (Spady, as cited in Asim et al. (2021). For OBE to be effectively implemented in higher education, a holistic approach is required. This includes the clear definition and alignment of Student Learning Outcomes (SLOs), Course Learning Outcomes (CLOs), and Program Learning Outcomes (PLOs), supported by robust assessment strategies and ongoing professional development for educators (Kennedy & Birch, 2020; Solikhah, 2022; Tam, 2014).

Educational processes are increasingly transitioning toward a learning outcomes-based approach. In this context, it is essential that assessments are properly aligned, as they serve a dual purpose: offering formative evaluation to support active learning and verifying whether students have acquired the intended knowledge, skills, and competencies (Crespo et al., 2010). Biggs, as cited in McArthur, (2023), introduced the concept of authentic assessment in higher education through the framework of constructive alignment, which emphasizes the connection between academic outcomes and workplace relevance. Therefore, clearly defining specific learning outcomes is crucial, as they articulate what students should know, be able to do, or demonstrate upon completing a course. Aligning these outcomes with real-world skills and competencies is essential for designing relevant learning activities and assessments that accurately reflect student achievement (Bhatia et al., 2018; Bhatti et al., 2023; Matsuzuka, 2020; Nguyen et al., 2024; Tam, 2014).

Integral to OBE is the Outcome-Based Assessment (OBA) process, which ensures that learning outcomes are effectively measured through a variety of assessment methods, including both formative and summative evaluations. OBA is a pedagogical approach that emphasizes not only students' academic performance but also their holistic development across multiple domains, with a particular focus on professional competencies and soft skills (Agir et al., 2023). However, transitioning from traditional assessment methods—such as assignments, quizzes, and examinations—to an OBA framework poses significant challenges for educators. Traditional assessments often yield a single, overall grade that lacks detailed insight into the attainment of specific learning outcomes, thereby limiting the ability to identify targeted areas for improvement (Damit et al., 2021). Additionally, the complexity of mapping and aggregating student performance across various levels of learning outcomes—SLOs, CLOs, and PLOs—further complicates the process and necessitates the use of robust, precise tools for data analysis (Admuthe & Loni, 2016).

Recent literature highlights the vital role of matrix models in addressing the challenges of outcome-based assessment by organizing and clarifying the hierarchical relationships among learning outcomes (Jacobs et al., 2022; Qadir et al., 2020; Ydesen, 2023). Matrix computations offer a robust method for representing many-to-many mappings between courses and outcomes, enabling the simultaneous quantification of attainment across multiple levels (Kavitha & Karthika, 2023; Shaikh & Kumar, 2022). By integrating both direct and indirect assessment data, matrix models strengthen the alignment between educational objectives and actual student performance, thereby supporting data-informed curriculum development (Bhatia et al., 2018; Rajak et al., 2019). For instance, the adoption of a programmable assessment matrix at the University of Wyoming enhanced assessment coordination and curriculum adaptability by systematically incorporating student feedback and tracking outcome attainment (Jacobs et al., 2022).

The active involvement of faculty members in the planning and implementation of the curriculum is essential (Simelane & Pillay, 2024). Such participation not only supports the curriculum development process but also fosters a sense of ownership, thereby enhancing faculty engagement and commitment (Chimbunde & Moreeng, 2024; Mogale, 2023). Despite progress in assessment strategies, the practical application of matrix models remains limited due to their inherent complexity and reliance on technical expertise. Faculty members often encounter major challenges in understanding and managing these models without specialized support, which hinders their widespread adoption (Bushchyk & Listopad, 2024; Ydesen, 2023). Furthermore, issues such as manual data collection, lack of automation, and limited administrative support compromise the accuracy and consistency of attainment calculations (Bhatti et al., 2023; Kadappa et al., 2022). Several studies also noted systemic barriers to effective OBE implementation, including increased workloads for educators, insufficient pedagogical transformation, and resistance to transitioning from content-based to outcome-based learning models (Admuthe & Loni, 2016; Mangali, 2021; Ydesen, 2023).

To address these challenges, automated tools such as Q-OBE have been developed to improve the accuracy of outcome attainment tracking and reporting, while minimizing human error and enhancing data management efficiency (Kadappa et al., 2022; Kavitha & Karthika, 2023). However, reliance on technological solutions does not eliminate the need for comprehensive faculty training and robust system infrastructure to ensure consistent and meaningful application. Additionally, there is a critical need for simplified matrix models that maintain mathematical rigor while offering user-friendly interfaces. Such models would empower educators to interpret and apply assessment data effectively without requiring advanced technical expertise (Gupta & Ghosal, 2021; Qadir et al., 2020).

Building on these insights, our research introduces a hierarchical weighting-based matrix model as a core component of the OBA framework. This model seeks to bridge the gap between complex, data-intensive assessment approaches and the practical constraints faced by educators in varied educational contexts. By streamlining the number of variables and utilizing simplified yet mathematically robust operations, the model enables accurate evaluation of SLOs, CLOs, and PLOs, while improving interpretability and ease of implementation. Validated within a real-world university setting, the model provides empirical evidence of its practicality and effectiveness, contributing to the advancement of research in outcome-based assessment.

Aim and Questions of the Study

The purpose of this research is to bridge the gap between traditional assessment methods and the complexities of outcome-based assessment by developing an accessible and accurate hierarchical weighting model. The core research questions guiding this study are: (1) How can matrix computations be simplified to improve the practical implementation of the OBA framework? (2) What methodologies can ensure that the assessment process accurately reflects the hierarchical relationships among SLOs, CLOs, and PLOs? (3) How can the model be optimized for usability by educators with varying levels of technical expertise? By addressing these questions, this study aims to contribute to the evolving discourse on OBE and provide educators with practical tools that enhance the assessment process, ultimately supporting improved educational outcomes.

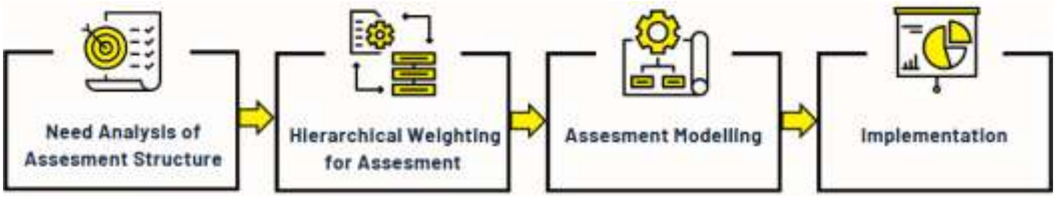
METHODOLOGY

Research Design

The methodology for this study consists of four distinct phases, each strategically designed to ensure alignment among Program Educational Outcome (PEOs), PLOs, CLOs, and SLOs.These phases are illustrated in Figure 1.

Figure 1.

Stages of the Hierarchical Weighting-Based Assessment



Need Analysis of Assessment Structure

The initial phase involves mapping the hierarchical relationships among PEOs, PLOs, CLOs, and SLOs to ensure vertical alignment within the curriculum. This step is essential for establishing a coherent assessment structure that aligns with the overarching educational objectives of the program.

The needs analysis was conducted through focus group discussions (FGDs) with key stakeholders, including lecturers, curriculum developers, administrators, and system operators. This qualitative approach aimed to identify challenges in aligning current assessment practices with OBE principles and to gather insights on the desired features of a new assessment system.

To ensure that instructors' needs in assessing student attainment were adequately addressed, a series of FGDs were conducted at the outset of the needs analysis. The primary objective of these discussions was to identify key factors that would support the development of an improved assessment process aligned with established learning objectives. Guided by a semi-structured questionnaire, the focus group discussions addressed key topics such as user management, effective curriculum mapping, specific requirements for assessment methods, and the content of assessment reports. Insights from this analysis formed the foundation for designing the hierarchical matrix-based assessment model, ensuring its relevance and usability in real-world educational settings.

Development of Hierarchical Weighting for Assessment

This phase focuses on the scoring method used to systematically measure the achievement of learning outcomes based on the hierarchical relationships among PLOs, CLOs, and SLOs. The process involves several key steps. The first is the definition of variables and parameters. In this step, the scoring method identifies and defines variables representing each level of learning outcomes, which must be quantified to enable mathematical measurement. At this stage, a score is assigned to reflect the correlation between variables—such as the relationship between CLOs and PLOs, and between sub-CLOs and CLOs. The determination of these scores is crucial for understanding how individual learning outcomes contribute to broader educational objectives. Each score not only confirms the existence of a relationship but also quantifies its strength. For example, a higher score assigned to a CLO shows a stronger contribution to the achievement of a specific PLO; similarly, a higher score for a sub-CLO reflects a greater impact on the corresponding CLO.

Assessment Modelling

The third stage, Assessment Modelling, involves developing a quantitative model to evaluate learning achievements using defined variables for each outcome level—SLOs, CLOs, and PLOs. This stage includes constructing hierarchical matrices to represent the relationships among outcomes and assigning weights to each level based on its relative importance. These weighted scores are then aggregated to assess overall program goal attainment. The model is validated using historical student data to ensure it accurately reflects the relationships between learning outcomes. This system facilitates automated data processing, score aggregation, and the generation of achievement reports, thereby ensuring alignment with the program's educational objectives.

Implementation

The final phase involves developing and testing the system to evaluate its effectiveness in measuring learning outcomes and ensuring curriculum alignment. The system is piloted within the Mathematics Education Department at the university level using actual assessment data at the SLO, CLO, and PLO levels. This phase comprises two key steps: system testing and system implementation. The process begins with preparing real student performance data, including grades from assignments, quizzes, and exams, all mapped to relevant SLOs, CLOs, and PLOs. This ensures proper data integration into the system, followed by testing the aggregation algorithm. The system must accurately aggregate student grade data across various levels and correctly apply the assigned weights for each outcome. Additionally, the system's output is cross verified against manually calculated results to ensure reliability and accuracy. The final step focuses on report generation. The system should be capable of producing detailed reports at the individual student, course, and program levels, clearly demonstrating each student’s achievement in relation to the defined learning outcomes.

Study Participants

The study participants included experienced lecturers, curriculum developers from different subject background, administrative staff, system operators, and senior students. All of them are the user of developed academic system. Their diverse roles provided a comprehensive perspective on the system's strengths and challenges. Participants were intentionally selected to represent all key stakeholders involved in the assessment process. Lecturers contributed insights into the practical complexities of implementing assessments within classroom settings. Curriculum developers and administrators offered perspectives on policy alignment, learning objectives, and reporting structures. System operators played a critical role in identifying technical requirements and necessary modifications to ensure the system's effective functionality.

Data Collection Tools

The study employed a combination of qualitative and quantitative data collection methods to ensure a comprehensive understanding of system requirements and user experience. In the initial phase, FGDs were conducted to gather qualitative insights into the challenges educators and administrators face when implementing assessment systems aligned with OBE. These discussions examined key issues such as curriculum mapping, assessment criteria, and reporting structures, offering essential input for the design of the hierarchical weighting model.

In the implementation and evaluation phase, the User Experience Questionnaire (UEQ) was employed as a structured instrument for collecting quantitative feedback on the developed system. The UEQ utilized bipolar Likert-type items to assess both pragmatic qualities—such as supportiveness, clarity, efficiency, and ease of use—and hedonic qualities—such as inventiveness, excitement, and innovation. To ensure objectivity and representativeness, participants were randomly selected from the pool of system users. The use of the UEQ aligns with the study’s objective of evaluating not only the system’s functional effectiveness but also its emotional and experiential impact on users.

Data Analysis Technique

The study utilized mixed-method analysis techniques to effectively interpret both qualitative and quantitative data. Thematic analysis was applied to the qualitative data gathered from FGDs to identify key patterns and insights. For the quantitative data, particularly the responses from the UEQ, descriptive statistical techniques were used to evaluate participants' perceptions of the system. Metrics such as mean values and standard deviations were calculated for each UEQ item to assess both the functional and experiential aspects of user interaction.

Furthermore, a series of matrix computations formed the foundation of the hierarchical assessment model used to analyze student performance data. Matrices R1, R2, and R3 were employed to represent the relationships among PLOs, CLOs, and (SLOs, as well as their connections to specific assessments. These were supported by the RW (weighted relationship) matrix and corresponding evaluation matrices to calculate both individual and aggregate achievement scores. This computational approach enabled precise tracking of outcome attainment and provided a robust framework for aligning assessments with defined learning objectives.

RESULTS AND DISCUSSION

Need Analysis of Assessment Structure

The needs analysis phase revealed several critical insights into the gaps and challenges encountered by educators and administrators in implementing an assessment system aligned with the OBE framework. Findings from the FGDs indicated that although current assessment practices addressed basic evaluation tasks, they lacked the structured framework and precision necessary to effectively measure learning outcome attainment across multiple levels.

The OBE curriculum employs a top-down hierarchical approach by systematically structuring PEOs, PLOs, CLOs, and SLOs. This structure ensures cohesive alignment from broad program goals to specific lesson outcomes, enabling educational objectives to be achieved at every level. Curriculum experts evaluate the interrelationships among PEOs, PLOs, CLOs, and SLOs to maintain coherence and ensure that each course contributes meaningfully to the broader educational goals. Figure 2 illustrates this hierarchical structure and its alignment within the curriculum.

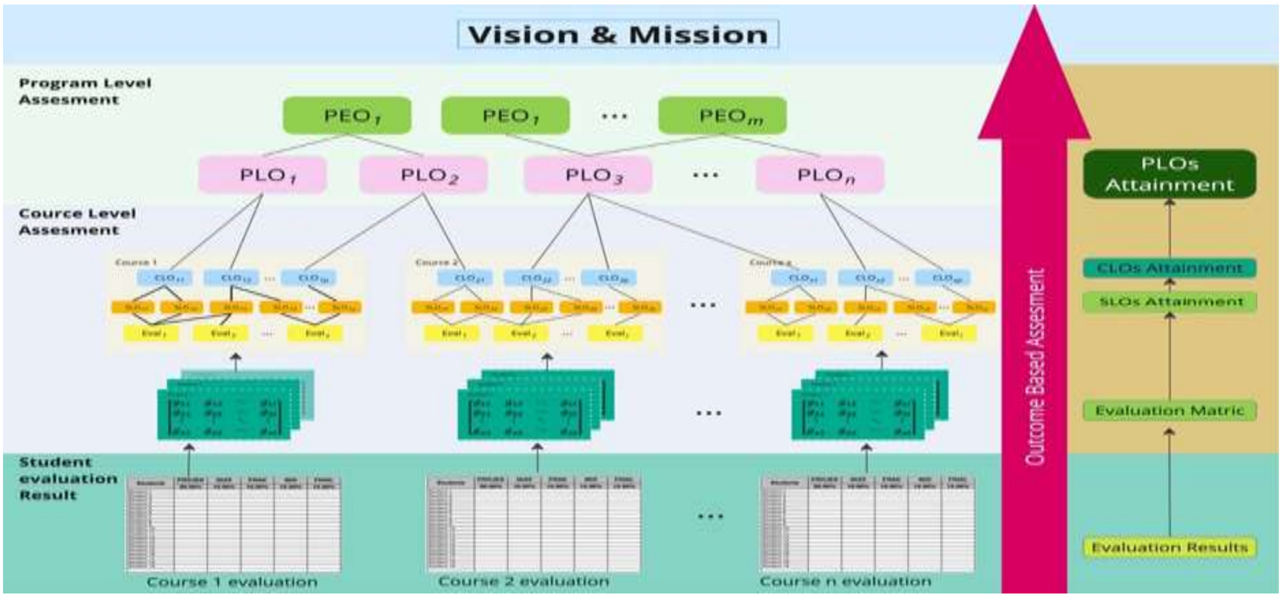
In the OBE curriculum, the OBA process begins with the evaluation of CLOs using student performance data from assignments, exams, and projects. This approach aligns with existing faculty practices, facilitating easier implementation by minimizing disruptions to instructors' usual workflows. To effectively measure CLOs, SLOs, and other outcomes, a mathematical model is required to disaggregate, aggregate, and map student scores to broader educational objectives. This model ensures alignment with curriculum goals and offers a structured framework for accurately tracking learning progression.

Similarly, PLOs, which represent the overall competencies expected of graduates, are evaluated by aggregating CLO achievements to assess alignment with program objectives.

Achievement refers to the measurable outcomes of specific tasks, whereas attainment reflects the level of mastery demonstrated upon program completion. Tracking both metrics ensures that students not only perform well in individual areas but also develop the comprehensive skills required for workforce readiness.

Figure 2.

Hierarchical Structure of OBE Curriculum Outcome



This structure aligns program goals with course and lesson outcomes, establishing a clear pathway for assessing student achievement. At the highest level, PEOs represent broad, long-term goals for graduates after completing the program. In contrast, PLOs define the specific competencies students are expected to achieve by the time of graduation, ensuring cohesive alignment from course-level outcomes to overarching program objectives.

Hierarchical weighting for Assessment

To represent the complex relationships among PLOs, CLOs, and SLOs, evaluation matrices are constructed to define represent and assign weights among these outcomes. These matrices quantify the relationships between PLOs, CLOs, SLOs, and their respective assessments using three relational matrices: $\mathrm{R1}$, $\mathrm{R2}$ and $\mathrm{R3}$. Matrix R1 defines the relationship between PLOs and CLOs, where PLOs are represented as $\mathrm{P} = \{\mathrm{P}_1, \mathrm{P}_2, \ldots, \mathrm{P}_\mathrm{m}\}$ where P_i denotes the i-th PLO, while CLOs are defined as $\mathrm{C} = \{\mathrm{C}_1, \mathrm{C}_2, \ldots, \mathrm{C}_\mathrm{n}\}$ where C_j denotes the j-th CLO. Each element in $\mathrm{R1}$, r_{ij}, reflects the degree of contribution of each CLO C_i to PLO P_j with values ranging from 0 (no contribution) to 3 (strong contribution). Matrix R2 links CLOs to SLOs, illustrating how course objectives support the achievement of specific student learning outcomes. Finally, Matrix R3 connects SLOs to assessment items, such as assignments and exams, indicating how each learning objective is assessed.

$$\mathrm{R1} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}, r_{ij} \in \{0,1,2,3\} \tag{1}$$

To ensure proper alignment between PLOs and CLOs, matrix $\mathrm{R1}$ must satisfy certain conditions. For each CLO C_i, the sum of its contributions across all PLOs must be at least 1, expressed as $\sum_{j=1}^{m} r_{ij} \geq 1$. Similarly, for each PLO P_i, the sum of contributions from all CLOs must also be at least 1, given by $\sum_{i=1}^{n} r_{ij} \geq 1$. These conditions ensure that every CLO contributes to at least one PLO and that each PLO is supported by at least one CLO. Matrix $\mathrm{R1}$ thus provides a comprehensive view of how CLOs align with and contribute to the achievement of PLOs, reinforcing that the program's learning outcomes effectively support its overarching educational objectives. This structured approach enhances curriculum coherence and enables more effective assessment and continuous improvement of the educational program.

Matrix R2 further clarifies the hierarchical structure by connecting CLOs to SLOs. SLOs are represented as $L = \{L_1, L_2, \ldots, L_k\}$, each indicating a specific SLO. The elements of R2, denoted as s_{ij}, range from 0 (no contribution) to 3 (strong contribution), showing the extent to which each SLO L_j supports the achievement of a given CLO C_i. To ensure that the course content effectively enhances learning across levels, R2 must satisfy a critical condition: For each CLO C_i the sum of its contributions to all SLOs must be at least 1, expressed as $\sum_{i=1}^{k} s_{ij} \geq 1$. This requirement ensures that every course objective contributes meaningfully to the development of specific learning outcomes, reinforcing the coherence and depth of the curriculum.

$$\mathrm{R2} = \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1m} \\ s_{21} & s_{22} & \cdots & s_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ s_{k1} & s_{k2} & \cdots & s_{km} \end{bmatrix}, s_{ij} \in \{0,1,2,3\} \tag{2}$$

Matrix $\mathrm{R3}$ completes the chain of relationships in the model by linking SLOs to their corresponding evaluations, typically represented through various types of assignments. Evaluations are catalogued as $E = \{E_1, E_2, \ldots, E_l\}$ where each E_i represents a distinct assessment or assignment type. Each element t_{ij} in R3, also valued from 0 to 3, quantify how comprehensively an SLO L_i is assessed by an evaluation E_j.

$$\mathrm{R3} = \begin{bmatrix} t_{11} & t_{12} & \cdots & t_{1k} \\ t_{21} & t_{22} & \cdots & t_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ t_{l1} & t_{l2} & \cdots & t_{lk} \end{bmatrix}, t_{ij} \in \{0,1,2,3\} \tag{3}$$

$$w = \{w_1, w_2, \ldots, w_l\}, \qquad \sum_{i=1}^{l} w_l = 100 \tag{4}$$

Additionally, each evaluation $\mathrm{E_i}$ is assigned a specific weight, representing its significance within the overall assessment framework. These weights are stored in a vector $\mathrm{w} = \{\mathrm{w_1}, \mathrm{w_2}, \dots, \mathrm{w_l}\}$, where each $\mathrm{w_i}$ is a percentage that sums up to 100%. This distribution allows certain assessments to be prioritized over others, depending on their relative importance or the depth of insight they provide into students' understanding and skill development.

Instructors conduct assessments based on the defined evaluations, resulting in the creation of an assessment matrix S. This matrix organizes the scores of x number of students in a structured format, where each row represents an individual student and each column corresponds to their score for a specific type of assessment.

$$\mathrm{S} = \begin{bmatrix} \mathrm{g_{11}} & \mathrm{g_{12}} & \cdots & \mathrm{g_{1l}} \\ \mathrm{g_{21}} & \mathrm{g_{22}} & \cdots & \mathrm{g_{2l}} \\ \vdots & \vdots & \ddots & \vdots \\ \mathrm{g_{x1}} & \mathrm{g_{x2}} & \cdots & \mathrm{g_{xl}} \end{bmatrix}, \ 0 \leq \ \mathrm{g_{i,j}} \leq 100 \qquad (5)$$

Assessment Modelling

The Assessment Model establishes a hierarchical framework that links evaluations to SLOs, which in turn connect to PLOs. This structure ensures that each individual assessment contributes meaningfully to the achievement of targeted learning outcomes, all of which are aligned with the program's overarching educational objectives. The steps required to calculate a student's attainment are as follows:

SLOs Attainment

To effectively measure the impact of various evaluations on SLOs, we calculate matrix $\mathrm{RW} = [\mathrm{rw_{ij}}]$ which determines the weighted contribution of each evaluation to the corresponding SLOs. Each element $\mathrm{rw_{ij}}$ of the matrix is calculated using the following criteria where $\mathrm{w_i}$ represents the weight of the i-th evaluation.

$$\mathrm{RW} = \begin{bmatrix} \mathrm{rw_{11}} & \mathrm{rw_{12}} & \cdots & \mathrm{rw_{1l}} \\ \mathrm{rw_{21}} & \mathrm{rw_{22}} & \cdots & \mathrm{rw_{2l}} \\ \vdots & \vdots & \ddots & \vdots \\ \mathrm{rw_{x1}} & \mathrm{rw_{x2}} & \cdots & \mathrm{rw_{xl}} \end{bmatrix}, \ \mathrm{rw_{ij}} = \frac{\mathrm{t_{ij}}}{\sum_{\mathrm{j=1}}^{\mathrm{k}} \mathrm{t_{ij}}} \times \ \mathrm{w_i} \qquad (6)$$

This calculation ensures that the matrix RW provides a balanced representation of how each evaluation contributes to learning outcomes, accounting for both the assigned weight of the evaluations and the extent to which they assess different SLOs. This approach enables educational practitioners to identify the most impactful assessments and understand how they support the achievement of specific levels of student learning.

To assess each SLO for each student, the RW matrix is multiplied by the student evaluation matrix S. This operation quantifies the extent to which each student has achieved the specified SLOs, translating their performance on individual evaluations into measurable learning outcome attainment.

$$\mathrm{O} = \begin{bmatrix} o_{11} & o_{12} & \cdots & o_{1l} \\ o_{21} & o_{22} & \cdots & o_{2l} \\ \vdots & \vdots & \ddots & \vdots \\ o_{x1} & o_{x2} & \cdots & o_{xl} \end{bmatrix},\ o_{ij} = \sum_{j=1}^{q} \frac{g_{ij} \times rw_{ij}}{\sum_{j=1}^{k} rw_{ij}} \tag{7}$$

Outcome Aggregation of SLOs to CLOs

SLOs are more granular objectives that directly support the achievement of CLOs. The primary input for assessing CLO attainment is derived from SLOs, with the relationship between CLOs and SLOs defined in matrix R2, as outlined in Equation 3. The initial step in the aggregation process involves summing the elements across each row of the R2 matrix by multiplying it with a unit matrix of size $\mathrm{k} \times 1$. This operation produces a vector S, which effectively captures the row-wise sums of the R2 matrix, representing the total contribution of SLOs to each CLO.

$$\mathrm{S} = \begin{bmatrix} \sum_{j=1}^{k} t_{j1} \\ \sum_{j=1}^{k} t_{j2} \\ \vdots \\ \sum_{j=1}^{k} t_{jm} \end{bmatrix} \tag{8}$$

Following the initial aggregation step, $\mathrm{R2}$, O, and S are combined using Equation 9, tom calculate the new matrix $\mathrm{O2}$. Each element of $\mathrm{O2}$, denoted as $s_{ij} \times o_{ij}/s_i$, is calculated by multiplying the corresponding elements from matrices $\mathrm{R2}$ and O, and then dividing each product by the sum of the elements in the respective row s_i of S. This operation normalizes the interaction between the matrices, ensuring that the resulting matrix $\mathrm{O2}$ provides a properly scaled aggregation of inputs, proportionally adjusted based on total contributions of each SLO to its associated CLO.

$$\mathrm{O2} = \begin{bmatrix} \frac{s_{11} \times o_{11}}{S_1} & \frac{s_{12} \times o_{11}}{S_1} & \cdots & \frac{s_{1p} \times o_{1p}}{S_1} \\ \frac{s_{21} \times o_{21}}{S_2} & \frac{s_{22} \times o_{22}}{S_2} & \cdots & \frac{s_{2p} \times o_{2p}}{S_2} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{s_{k1} \times o_{k1}}{S_k} & \frac{s_{k2} \times o_{k2}}{S_k} & \cdots & \frac{s_{kp} \times o_{kp}}{S_k} \end{bmatrix} \tag{9}$$

By applying the calculations outlined in Equation 9, the achievement score for each CLO can be determined for individual students. This process aggregates the contributions of relevant SLOs, weighted by their respective impact on each CLO. As a result, the derived CLO scores offer a clear and accurate measure of how effectively students are meeting broader course objectives, based on their performance across the more specific and detailed SLOs.

Outcome Aggregation of CLOs to PLOs

To aggregate CLOs into PLOs, the aggregation results from the previous step, represented by matrix $\mathrm{O2}$, are utilized. This process mirrors the method used for aggregating SLOs into CLOs.

The first step involves calculating the vector S', which is obtained by summing the columns of matrix R3.

$$S' = \begin{bmatrix} \sum_{j=1}^{l} r_{j1} \\ \sum_{j=1}^{l} r_{j2} \\ \vdots \\ \sum_{j=1}^{l} r_{jk} \end{bmatrix} \tag{10}$$

As with the previous aggregation, normalization is applied to ensure proportional weighting. Each element in a row of the R3 matrix is divided by the corresponding row sum, ensuring that each row sums to 1. This normalization allows for a balanced contribution of CLOs to PLOs. The final aggregation is then calculated by multiplying the normalized R3 matrix with the O2 matrix, producing a matrix that reflects each student's achievement of PLOs based on their performance across CLOs.

$$O3 = \begin{bmatrix} \frac{t_{11} \times o2_{11}}{S'_1} & \frac{t_{12} \times o2_{11}}{S'_1} & \cdots & \frac{t_{1p} \times o2_{1p}}{S'_1} \\ \frac{t_{21} \times o2_{21}}{S'_2} & \frac{r_{22} \times o2_{22}}{S'_2} & \cdots & \frac{t_{2p} \times o2_{2p}}{S'_2} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{t_{l1} \times o2_{l1}}{S'_l} & \frac{t_{l2} \times o2_{l2}}{S'_l} & \cdots & \frac{t_{lp} \times o2_{lp}}{S'_l} \end{bmatrix} \tag{11}$$

The $O3$ matrix maps course-level objectives to broader program goals. This matrix providing a clear representation of the outcomes of individual courses contribute to the overall educational objectives of the program.

Implementation

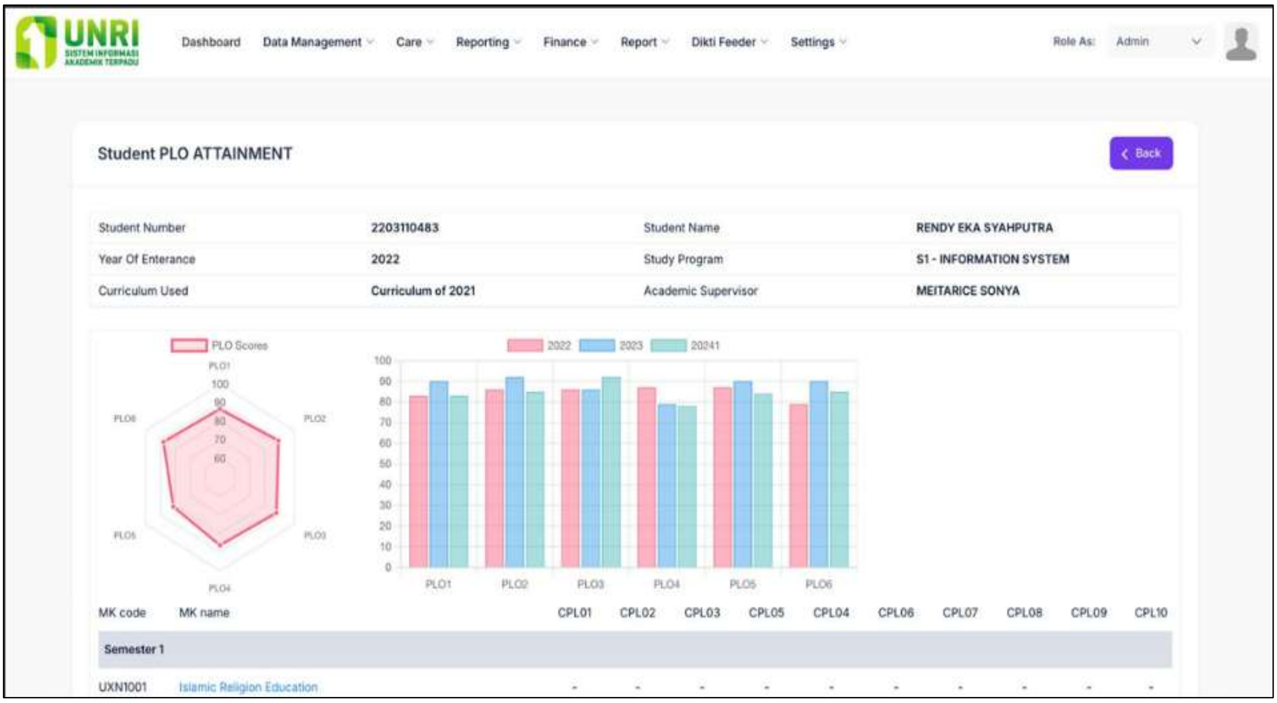
The system automates contribution calculations by dynamically updating the RW matrix as new assessment data is entered. This matrix serves as a foundation for calculating SLO achievement, which is algorithmically linked to CLOs and, ultimately, to PLOs. Additionally, the system features reporting tools that visualize outcomes in various formats, enabling educators to analyze data effectively and make informed decisions for curriculum improvements. The requirements gathering and analysis phase defines the system's objectives by incorporating input from key stakeholders, including the Curriculum Development Centre and the Mathematics Education Program, and is supported by findings from previous research (Andriyani et al., 2022; Mazouz & Crane, 2013; Ramadhani et al., 2023).

In the System Design phase, the system's architecture is defined by implementing models for normalized contributions to SLOs, CLOs, and PLOs using matrices R1, R2, R3, and W and attainment formulas. Dashboards and reports are designed to provide clear and accessible data visualization. During the Development Phase, the system is programmed to manage calculations through dedicated modules for tracking SLO, CLO, and PLO attainment. User-friendly data input methods are integrated to streamline entry, while robust database schemas and APIs ensure secure data storage and system flexibility.

The implementation results are illustrated in Figure 3, which displays the individual student achievement report. This report offers detailed insights into each student's performance relative to specified learning outcomes and serves as a vital tool for the continuous improvement of instruction and assessment. Users can also access these reports retrospectively, enabling comprehensive analysis of performance trends over time. The interface plays a key role in administrative processes and detailed grade reporting, ensuring alignment with the institution’s broader educational objectives.

Figure 3.

Screen-Shoot of Student Attainment Report



Student PLO ATTAINMENT

Student Number	2203110483	Student Name	RENDY EKA SYAHPUTRA
Year Of Enterance	2022	Study Program	S1 - INFORMATION SYSTEM
Curriculum Used	Curriculum of 2021	Academic Supervisor	MEITARICE SONYA

MK code	MK name	CPL01	CPL02	CPL03	CPL05	CPL04	CPL06	CPL07	CPL08	CPL09	CPL10
Semester 1											
UXN1001	Islamic Religion Education	-	-	-	-	-	-	-	-	-	-

Once the system is developed, it enters the testing phase, during which it undergoes rigorous evaluation for functionality, calculation accuracy, and overall usability. This process ensures that the system operates as intended and that any errors or technical issues are identified and resolved. End-users, including educators and administrative staff, participate in UAT to validate the system’s performance in real-world educational settings and confirm its readiness for deployment.

In the system evaluation phase, the UEQ includes a comprehensive set of eight items, each targeting specific aspects of user interaction and satisfaction across both pragmatic and hedonic dimensions. Pragmatic quality items assess the system’s functional performance and include supportiveness (Item 1), ease of use (Item 2), efficiency (Item 3), and clarity (Item 4), capturing how effectively users feel the system supports their tasks. Hedonic quality items evaluate the emotional and experiential engagement of the system, focusing on attributes such as excitement (Item 5), interest (Item 6), inventiveness (Item 7), and cutting-edge appeal (Item

8), which reflect its ability to stimulate and engage users. The results of this evaluation are presented in Table 1, providing a quantitative summary of each item's mean, variance, and standard deviation, thus presenting a detailed overview of the system's performance across these key user experience dimensions.

Table 1.
User Experience Questionnaire Result

Item	Mean	Variance	Std. Dev.	Negative	Positive
1	1.61	0.63	0.79	Obstructive	Supportive
2	0.21	0.55	0.74	Complicated	Easy
3	1.14	0.72	0.85	Inefficient	Efficient
4	1.79	0.65	0.81	Confusing	Clear
5	0.13	0.32	0.56	Boring	Exciting
6	0.11	0.24	0.49	Not interesting	Interesting
7	1.65	0.72	0.85	Conventional	Inventive
8	1.74	0.48	0.69	Usual	Leading edge

Based on the UEQ results from a random sample of 225 users, the developed system shows strong performance across several key dimensions, particularly in terms of both pragmatic and hedonic qualities. Users consistently rated the system highly for its supportiveness and efficiency, indicating that it effectively facilitates task completion through a user-friendly and intuitive interface. This is reflected in the high mean scores for clarity (Item 4: 1.79) and supportiveness (Item 1: 1.61), suggesting that the system enhances user interactions rather than complicating them. Furthermore, the system is perceived as innovative and forward-thinking, as shown by high ratings for inventiveness (Item 7: 1.65) and being leading-edge (Item 8: 1.74). These results highlight the system's ability to introduce novel functionalities and approaches, distinguishing it from standard solutions and making it especially valuable in technology-driven educational environments.

Despite the overall positive feedback, the evaluation reveals areas for improvement, particularly concerning the system's hedonic quality. The neutral scores for excitement and interest (Items 5 and 6, both with means of 0.13 and 0.11) indicate that while the system does not disengage users, it also lacks elements that actively captivate or stimulate them. Enhancing the visual interface, incorporating interactive features, or integrating gamification elements could help make the user experience more engaging. Additionally, although the system is not perceived as difficult to use (Item 2 mean: 0.21), this neutral rating suggests room for usability enhancements. Streamlining complex processes, improving onboarding tutorials, and refining user workflows could further increase ease of use while maintaining the system's core functionality.

DISCUSSION

Central to this approach are the matrix models (R1, R2, and R3), which quantitatively define and evaluate the relationships among different levels of learning outcomes. These matrices provide a structured and systematic method for evaluating how effectively specific Course Learning Outcomes (CLOs) support the attainment of Program Learning Outcomes (PLOs), and ultimately, the broader Program Educational Objectives (PEOs). The use of these models aligns with the principles of backward design, which advocate beginning with clearly defined outcomes to inform and guide the entire educational process (Admuthe & Loni, 2016; Mazouz & Crane, 2013; Vijayalakshmi et al., 2013). Matrix R1 defines the contribution of each CLO to the corresponding PLOs, ensuring that every course outcome substantively supports at least one program-level objective. This matrix highlights the importance of aligning course content with broader curricular goals, promoting coherence and relevance throughout the educational experience (Bushchyk & Listopad, 2024; Damit et al., 2021). By establishing explicit connections between CLOs and PLOs, educators can design curricula that are not only aligned with institutional objectives but also responsive to student needs and the evolving demands of the job market.

Matrix R2 extends this relationship by linking CLOs to more detailed SLOs, clarifying how individual lessons contribute to broader course objectives. This alignment ensures that each lesson is intentionally designed to build on prior knowledge and skills, reinforcing the course's targeted outcomes. The structured framework of Matrix R2 enables granular analysis of student progress, allowing educators to pinpoint specific areas of difficulty and adapt their instructional strategies accordingly. This level of responsiveness is essential for promoting continuous improvement and supporting personalized learning pathways.

Matrix R3 completes the outcome mapping by linking SLOs to specific assessments, such as exams, projects, and assignments. This connection provides a clear and measurable pathway to evaluate whether learning objectives are being achieved through academic assessments. Such alignment is essential for enabling educators to refine teaching strategies and instructional materials based on empirical evidence, thereby enhancing overall educational effectiveness. By directly correlating assessment results with learning outcomes, Matrix R3 supports a data-informed approach to curriculum development and instructional design, ensuring that essential competencies are effectively addressed throughout the curriculum (Alfauzan & Tarchouna, 2017; Hoadley & Sabri, 2016; Yan et al., 2023).

While the hierarchical and structured approach to curriculum design provides numerous benefits, it is important to recognize its limitations. A primary concern is the complexity involved in implementing and maintaining the matrix models, which may require extensive training for educators and major resources during the initial setup. Moreover, the emphasis on quantitative measurement can inadvertently downplay qualitative dimensions of learning—such as student engagement, creativity, and critical thinking—that are vital for a well-rounded education. The effectiveness of these models also depends heavily on the accuracy and consistency of the data collected, which can be compromised by issues related to assessment design, student participation, and data interpretation.

In terms of comparative advantages, matrix models offer a systematic framework that strengthens alignment and coherence within the curriculum, enabling data-driven assessment and ongoing improvement of educational programs (Lavanya & Murthy, 2022; Rajak et al., 2019). By systematically mapping relationships among learning outcomes and applying mathematical models, institutions can evaluate and adapt the curriculum more effectively to meet evolving educational objectives (Kadappa et al., 2022; Shallal, 2018). This structured approach promotes transparency and accountability while fostering a culture of evidence-based decision-making among educators and administrators.

Connecting these findings to the broader theoretical framework, the use of matrix models aligns closely with constructivist learning theories, which emphasize the active engagement of students in the learning process. By clearly defining learning outcomes and aligning assessments with those outcomes, educators can design more meaningful and engaging learning experiences that promote student autonomy and ownership. This alignment is critical for ensuring that key competencies are systematically addressed throughout the curriculum, effectively preparing students to meet future academic, professional, and personal challenges.

In relation to the research questions posed in this study, the findings show that simplifying matrix computations enhances the practical implementation of the OBA framework. The hierarchical weighting-based matrix model offers a structured and systematic approach that enables educators to effectively evaluate the relationships among SLOs, CLOs, and PLOs, addressing the limitations and complexities often associated with traditional assessment methods. Moreover, the model is designed with usability in mind, accommodating educators with varying levels of technical expertise and making data-driven assessment practices more accessible and widely adoptable across educational settings.

CONCLUSION

The hierarchical alignment of PEOs, PLOs, CLOs, and SLOs within the curriculum ensures a cohesive and goal-oriented educational structure. By systematically connecting each level through matrix models, the curriculum is designed to ensure that every learning objective is explicitly supported and effectively assessed. The implementation of matrices such as R1, R2, and R3 establishes a clear and measurable framework for evaluating how specific outcomes contribute to broader program goals. This study found that the model simplifies user interaction rather than adding complexity, as reflected in a mean score of 1.6 on the UEQ, and the system was also perceived as innovative and forward-thinking, with a mean score of 1.7.

To enhance the effectiveness of curriculum alignment and assessment strategies, several strategic improvements are recommended. First, implementing a regular review and update cycle for the matrix models is essential to maintain alignment with evolving educational standards and practices. This process should actively engage stakeholders from diverse disciplines to ensure that the models reflect a broad range of perspectives and meet the dynamic needs of the curriculum. Second, prioritizing continuous professional development and training for educators on the effective use of these matrix models will promote consistent and accurate implementation, thereby maximizing their impact on learning outcomes. Finally, integrating qualitative feedback mechanisms alongside the quantitative matrix models will offer a more holistic and nuanced evaluation of curriculum effectiveness, capturing both measurable performance data and experiential insights.

In conclusion, the hierarchical weighting-based matrix models present a promising framework for advancing educational assessment practices. By recognizing both their strengths and limitations, this study highlights the need for ongoing refinement and adaptability within educational environments. The findings support improved student learning outcomes and institutional effectiveness, reinforcing higher education’s mission to equip graduates for future challenges. Moving forward, efforts should focus on enhancing these models by integrating qualitative dimensions of learning, increasing automation capabilities, and providing comprehensive training and support for faculty. Such developments will ensure that matrix-based assessment frameworks continue to evolve as effective tools for promoting educational quality and student success.

Acknowledgements

The research team acknowledges the support of the Directorate of Research, Technology, and Community Service (DRTPM) for providing the research grant under Contract Number: 083/E5/PG.02.00.PL/2024, dated June 11, 2024.

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