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Reframing Assessment in Higher Education: Integrating Competency-Based and Adaptive Digital Assessment for 21st Century Learning Outcomes

Reformulando la evaluación en la educación superior: integrando la evaluación basada en competencias y la evaluación adaptativa digital para los resultados de aprendizaje del siglo XXI

Novrianti Novrianti[i]
Alwen Bentri[i]
Zelhendri Zen[i]
Serli Marlina[i]

[i.] *Faculty of Education; Universitas Negeri Padang; Padang; Indonesia*

Corresponding author: Novrianti Novrianti.
email: novrianti@fip.unp.ac.id

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Abstract

This study aimed to explore how competency-based education (CBE) principles can be effectively integrated into adaptive digital assessment systems to enhance learning outcomes. Using a design-based research (DBR) methodology with 58 participants (faculty, instructional designers, and students) across three Indonesian public universities, this study developed and empirically validated the first scalable framework merging CBE with adaptive assessments. Using a design-based research methodology across three Southeast Asian public universities, the study involved faculty, instructional designers, and students in co-developing, implementing, and evaluating an integrated assessment model. Through iterative co-design workshops, the researchers operationalized three competency domains (cognitive reasoning, situational judgment, and communication proficiency) into an adaptive Moodle/H5P prototype using IRT-based branching logic. Data were collected through semi-structured interviews, document analysis, system logs, and focus group discussions and analyzed using thematic and descriptive statistical techniques. Mixed-methods data (interviews, system logs, focus groups) revealed a 25 % increase in student engagement ($M = 28.3$ vs. 22.6 minutes, $p < 0.05$, Cohen's $d = 0.7$) and 91 % feedback uptake, with qualitative themes highlighting improved self-regulation and faculty buy-in through participatory design. Results revealed that adaptive assessments enhanced learner engagement, self-regulation, and feedback responsiveness, while also making competencies more observable and assessable. The integration can bridge theory and practice in ways that support learner diversity, agency, and contextual relevance. This study advances the field by demonstrating how stakeholder co-ownership and embedded feedback mechanisms can reconcile competency-based rigor with adaptive personalization—a critical step toward equitable 21st-century assessment systems.

Keywords: adaptive assessment, competency-based education, design-based research, digital learning, feedback, higher education.

Ethics statement

This study was approved by the Ethics Committee of Universitas Negeri Padang (Approval No. 261/UN 35.13/LT/2024). All participants provided written informed consent prior to their participation.

Authors' contribution:

Novrianti Novrianti: Conceptualization, formal analysis, project administration, writing-original draft.

Alwen Bentri: Data curation, resources, software.

Zelhendri Zen: Investigation, methodology, supervision, writing-review and editing.

Serli Marlina: Funding acquisition, validation, visualization.

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Resumen

Este estudio tuvo como objetivo explorar cómo los principios de la educación basada en competencias (EBC) pueden integrarse eficazmente en los sistemas de evaluación digital adaptativa para mejorar los resultados del aprendizaje. Mediante una metodología de investigación basada en el diseño (DBR), con 58 participantes (profesorado, diseñadores instruccionales y estudiantes) de tres universidades públicas de Indonesia, el presente estudio desarrolló y validó empíricamente el primer marco escalable que fusiona la EBC con las evaluaciones adaptativas. Utilizando una metodología de investigación basada en el diseño en tres universidades públicas del sudeste asiático, el estudio involucró al profesorado, a diseñadores instruccionales y estudiantes en el desarrollo, la implementación y la evaluación de un modelo de evaluación integrado. Mediante talleres iterativos de codiseño, se operacionalizaron tres dominios de competencia (razonamiento cognitivo, juicio situacional y competencia comunicativa) en un prototipo adaptativo Moodle/H5P, utilizando la lógica de ramificación basada en TRI. Los datos se recopilaron mediante entrevistas semiestructuradas, análisis de documentos, registros del sistema y debates en grupos focales, y se examinaron a partir de técnicas estadísticas temáticas y descriptivas. Los datos de métodos mixtos (entrevistas, registros del sistema y grupos focales) revelaron un aumento del 25 % en la participación estudiantil (M = 28.3 vs. 22.6 minutos, $p < 0.05$, d de Cohen = 0.7) y un 9 1% de aceptación de la retroalimentación. Los temas cualitativos destacaron una mejor autorregulación y la aceptación del profesorado, por medio de un diseño participativo. Los resultados revelaron que las evaluaciones adaptativas mejoraron la participación, la autorregulación y la capacidad de respuesta frente a la retroalimentación por parte del alumnado, a la vez que hicieron que las competencias fueran más observables y evaluables. Esta integración puede conectar la teoría con la práctica, apoyando la diversidad, la autonomía y la relevancia contextual del alumnado. Este estudio supone un avance en el campo al demostrar cómo la copropiedad de las partes interesadas y los mecanismos de retroalimentación integrados pueden conciliar el rigor basado en competencias con la personalización adaptativa, un paso fundamental hacia sistemas de evaluación equitativos del siglo XXI.

Palabras clave: evaluación adaptativa, educación basada en competencias, investigación basada en diseño, aprendizaje digital, retroalimentación, educación superior.

Introduction

Assessment has long been at the heart of teaching and learning in higher education, serving as both a diagnostic and summative instrument to evaluate student performance, guide instructional decisions, and ensure accountability. In this study, we adhere to a distinction where "assessment" refers to the process of gathering evidence of student learning and performance, while "evaluation" implies a broader judgment of the worth or quality of a program or process. Our primary focus is on refining the assessment of individual student competencies. However, as the landscape of higher education undergoes rapid transformation—driven by digital innovation, global skills shortages, and the demand for graduate employability—traditional assessment practices are increasingly being challenged for their lack of alignment with the competencies required in contemporary workplaces (Brown, 2024; Evans & Waring, 2024a). There is growing consensus that 21st-century learning demands assessment systems that move beyond static evaluations of content recall toward more dynamic models capable of capturing authentic, contextual, and adaptive student learning outcomes (Brown, 2024; Masaiti *et al.*, 2023; Shavelson, 2023). A 2025 meta-analysis by Hussain *et al.* revealed that 68 % of employers perceive traditional exams as poor predictors of workplace readiness, underscoring the urgency for reform.

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Competency-based education (CBE) has emerged as a viable framework for achieving this goal. Rooted in the principle that learning should be measured by demonstrated mastery rather than time spent in instruction, CBE focuses on students' ability to apply knowledge, skills, and attitudes in real-world settings (Hundley & Keith, 2023; Ndeezi *et al.*, 2023). When integrated effectively, CBE has been shown to increase student agency, improve learning transparency, and enhance alignment with industry and professional standards (Bok *et al.*, 2024; Norman-Eck *et al.*, 2023). Yet, despite its theoretical appeal, many higher education institutions continue to rely on conventional assessments that inadequately capture the complex, multidimensional competencies demanded by CBE frameworks (Shadan *et al.*, 2025).

A parallel concern lies in the lack of adaptivity in current assessment systems. Traditional assessment forms, such as standardized final exams and fixed-form multiple-choice tests, assume a uniform standard of difficulty for all learners, disregarding the variability in students' prior knowledge, cognitive readiness, and learning pace. As a response, computer-adaptive testing (CAT) and item response theory (IRT)-based assessments offer more personalized, efficient, and psychometrically robust approaches to assessing individual competencies (Cheung *et al.*, 2024; Cumming & Miller, 2023). However, in most educational contexts, especially in developing countries, the application of adaptive and technology-enhanced assessment models remains sporadic and underutilized (Brown *et al.*, 2023; Deliwe & Zvapano, 2024). Even where technological integration has occurred—such as during the post-pandemic shift to digital learning—efforts have often focused on digitizing conventional assessments rather than rethinking their conceptual underpinnings (Awajan, 2023; Xiong *et al.*, 2023).

The convergence of these two underdeveloped yet highly promising domains—competency-based assessment and adaptive evaluation—presents a unique opportunity to reframe the assessment paradigm in higher education. Integrating them into a unified framework can foster more equitable, accurate, and meaningful evaluations that not only reflect what students know but also how well they can perform in diverse and evolving contexts (Forsyth *et al.*, 2024; Shavelson, 2023). Such a transformation aligns with recent global and national policy shifts emphasizing accountability, transparency, and lifelong learning readiness (Hussain *et al.*, 2025; Jin *et al.*, 2025).

Nevertheless, significant gaps remain in both theory and practice. First, there is limited empirical and conceptual work on how to operationalize competency-based learning outcomes within adaptive digital assessment systems. Second, few studies have proposed scalable models that can be integrated into institutional teaching and learning frameworks while also being sensitive to ethical, pedagogical, and technological considerations (Kiesler *et al.*, 2024; Naithani *et al.*, 2024). Third, there is a lack of robust evidence on the impact of integrated competency-adaptive assessment models on student engagement, feedback responsiveness, and long-term learning performance.

To address these gaps, this study explores the conceptual integration of competency-based education and adaptive assessment systems to support learning outcomes in higher education. The research aims to provide a theoretical and practical model that can guide institutional adoption of integrated assessments that are both rigorous and responsive to learner diversity.

This study is guided by the following research questions:

1. How can competency-based principles be effectively integrated into adaptive assessment frameworks in higher education?

2. What are the theoretical and practical implications of combining CBE and adaptive evaluation for improving learning outcomes?
3. What model can be proposed to guide institutions in implementing integrated competency-adaptive assessments that are scalable and pedagogically sound?

By investigating these questions, the study aims to contribute to the rethinking of assessment practices in higher education, aligning them with the core demands of the 21st-century learner and the evolving global educational landscape.

Literature Review

The evolution of assessment in higher education has been extensively documented, revealing persistent tensions between traditional evaluation practices and emerging demands for more authentic, competency-based, and adaptive approaches. This literature review critically examines existing empirical studies and theoretical frameworks related to competency-based education (CBE), adaptive assessment models, and their integration within higher education contexts.

Competency-Based Education and Assessment

Competency-based education has gained considerable traction as a transformative approach emphasizing demonstrated mastery of skills over time-based metrics (Hundley & Keith, 2023; Ndeezi *et al.*, 2023). Rooted in constructivist and outcomes-based pedagogies, CBE frameworks prioritize real-world application, reflective of industry and societal needs (Bok *et al.*, 2024; Norman-Eck *et al.*, 2023). Empirical investigations, such as those by Ndeezi *et al.* (2023), have highlighted the positive impact of CBE in fostering student agency and transparency in learning. Similarly, Bok *et al.* (2024) demonstrated how integrating workplace-based assessments such as Entrustable Professional Activities can enhance the relevance and authenticity of competency evaluation.

However, despite these promising developments, critiques abound regarding the operationalization of CBE in higher education. Shadan *et al.* (2025) argue that many institutions struggle to move beyond superficial adoption of competency frameworks, resulting in assessments that inadequately capture the multidimensional and contextual nature of competencies. Moreover, Nkealah (2023) and Brown (2024) emphasize the risk of increased faculty workload and assessment fatigue without corresponding systemic support or innovative assessment designs. These critiques reveal a disconnect between CBE theory and its effective implementation—particularly in contexts where institutional inertia favors traditional summative assessments.

Adaptive Assessment Models

Parallel to the rise of CBE, adaptive assessment technologies have emerged as an innovative solution to personalized assessment challenges. Computer-adaptive testing (CAT) and item response theory (IRT)-based models offer dynamic, learner-responsive assessment environments that can adjust item difficulty based on individual student responses, thereby enhancing measurement precision and learner engagement (Cumming & Miller, 2023; Cheung *et al.*, 2024). Such models have been particularly effective in high-stakes professional education settings, as evidenced by Cheung *et al.*'s (2024) national postgraduate medical education assessment program, which successfully integrated adaptive mechanisms to better reflect learner competencies.

Nevertheless, the widespread implementation of adaptive assessments is often constrained by technological infrastructure deficits, faculty training gaps, and socio-economic

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barriers (Brown *et al.*, 2023; Deliwe & Zvapano, 2024). Even in contexts where digital learning has accelerated due to the COVID-19 pandemic, the shift often amounted to digitizing existing assessment forms without rethinking assessment design or conceptual underpinnings (Awajan, 2023; Xiong *et al.*, 2023). This suggests that the potential of adaptive assessments remains underexploited in many higher education settings, calling for more thoughtful integration that considers pedagogical and ethical dimensions.

Integration of Competency-Based and Adaptive Assessments

The convergence of competency-based and adaptive assessment approaches represents a relatively nascent area of inquiry with high transformative potential. Shavelson (2023) advocates for frameworks that capture both what students know and how they can apply knowledge across contexts, aligning well with the competencies and flexibility demanded by 21st-century learning. Forsyth *et al.* (2024) further argue that integrating these models can promote equitable and personalized assessment systems that enhance feedback quality and student motivation.

Few empirical studies rigorously explore operational frameworks for this integration. Kiesler *et al.* (2024) and Naithani *et al.* (2024) emphasize the complexity of merging competency taxonomies with adaptive testing algorithms while maintaining ethical standards around data privacy and assessment fairness. Moreover, Murugan *et al.* (2025) highlight that artificial intelligence tools, while promising for enhancing assessment adaptivity and competency mapping, require further research to establish reliable and valid models within institutional teaching frameworks.

Existing literature also lacks robust longitudinal studies evaluating how integrated competency-adaptive assessments influence student engagement, feedback responsiveness, and learning trajectories over time. David (2025) and Nusri *et al.* (2025) call for more nuanced research exploring how these integrated models impact not only immediate performance but also learners' capacity for lifelong learning and adaptability in evolving professional landscapes.

Addressing the Research Gaps

This review reveals three key gaps: (1) limited empirical evidence and conceptual models detailing how to embed competency-based learning outcomes within adaptive digital assessment systems, (2) scarce scalable, pedagogically sound frameworks for institutional adoption sensitive to ethical, technological, and contextual factors, and (3) insufficient understanding of the impact of integrated assessments on long-term student learning engagement and performance.

By focusing on these underexplored intersections, the present study aims to advance theoretical understanding and offer practical guidance for higher education institutions. Investigating the integration of competency-based and adaptive assessments addresses a critical need to rethink assessment paradigms aligned with the demands of the 21st-century learner, thereby bridging theory and practice while responding to policy imperatives emphasizing accountability and lifelong learning readiness (Hussain *et al.*, 2025; Jin *et al.*, 2025).

Methods

Research Design

This study employed a qualitative-dominant mixed-methods design embedded within a design-based research (DBR) framework, appropriate for developing and evaluating

innovative educational interventions in authentic learning environments (McKenney & Reeves, 2019). The mixed-methods approach was selected to capture both the depth and breadth of perspectives on integrating competency-based education (CBE) and adaptive assessment in higher education. Qualitative data provided nuanced insights into stakeholder experiences, while quantitative components contributed to the validation of emergent models and patterns.

Design-based research was particularly suitable for this study due to its iterative nature, focus on practical problem-solving, and integration of theory-building with contextual relevance (Anderson & Shattuck, 2012). The study unfolded over three iterative phases: contextual analysis, model co-design and implementation, and evaluation and refinement, corresponding to the DBR cycle. This allowed for triangulation across multiple data sources and stakeholders to ensure ecological validity and practical utility of the proposed integrated assessment model.

Research Context

The research was conducted at three public universities in Southeast Asia, which have recently begun exploring reforms in their assessment systems through digital platforms and outcomes-based curricula. All three institutions had institutional mandates for implementing elements of CBE and digital learning tools but lacked structured integration frameworks. The institutional settings were chosen for their diversity in faculty development, digital infrastructure, and policy readiness, providing a realistic testing ground for exploring scalable and transferable practices.

Participants

Participants included faculty members, instructional designers, and final-year undergraduate students from education and health sciences programs. Purposive sampling was used to select participants with direct experience in competency-based teaching or digital assessments. A total of 58 individuals participated in the study: 21 faculty members, 5 instructional designers, and 32 undergraduate students. Faculty and designers participated in model development and reflection, while students participated in pilot implementation and feedback activities. All participants were invited through formal letters of consent, and their selection was guided by the principle of information-rich cases (Patton, 2015), ensuring diverse yet relevant viewpoints. Table 1 presents the demographic distribution of the participants.

Table 1
Participant Demographics

Category	Subcategory	Frequency (n)	Percentage (%)
Gender	Female	33	56.9
	Male	25	43.1
Role	Faculty Member	21	36.2
	Instructional Designer	5	8.6
	Student	32	55.2
Discipline	Education	31	53.4
	Health Sciences	27	46.6
Prior CBE Experience	Yes	18	31.0
	No	40	69.0
Digital Assessment Use	Frequent	22	37.9
	Occasional	36	62.1

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Instruments and Materials

The data collection process involved three primary instruments: semi-structured interviews, document analysis protocols, and a competency-adaptive assessment prototype. Each of them can be explained as below:

Three distinct semi-structured interview protocols (for faculty, instructional designers, and students, respectively) were developed based on the research questions and relevant literature (Creswell & Poth, 2018). Each protocol contained between 8 and 12 core questions. Questions focused on participants' experiences with CBE, challenges in implementing adaptive assessments, and perceptions of integrated assessment models. Interviews were piloted with two faculty members to ensure clarity and reliability. Document analysis involved reviewing institutional curriculum blueprints, learning outcomes, and assessment rubrics. This process followed the principles of qualitative document analysis (Bowen, 2009), which included skimming (superficial examination), reading (thorough examination), and interpretation, focusing on identifying explicit and implicit themes related to CBE integration and assessment practices. This helped to map existing CBE practices and identify gaps in current digital assessment integration. A prototype of the integrated competency-adaptive assessment model was co-developed using iterative feedback from faculty and instructional designers. The prototype was deployed on Moodle, integrated with H5P and IRT-enabled question banks to simulate adaptivity. Students interacted with the system during microteaching simulations and clinical scenario assessments, depending on their disciplines.

Data Collection Procedures

Data collection was conducted over a six-month period from January to June 2025, involving three phases aligned with the DBR methodology (Table 2).

Table 2
Triangulated Across Phases

Phase	Data Type	Instrument	Sample
Contextual Analysis	Curriculum documents	Rubric audit protocol (34 rubrics)	3 institutional policies
Co-Design	Workshop transcripts	Semi-structured discussion guides	6 sessions (18 hours)
Pilot Testing	System logs	Time-on-task, pathway analytics	32 students
Evaluation	Focus groups	Thematic discussion prompts	8 groups (4–6/group)

In the first phase, contextual analysis was conducted through 18 semi-structured interviews and document analysis of curricula and institutional policies. The second phase focused on co-design workshops, where faculty and designers collaboratively developed assessment blueprints and aligned competency indicators. These workshops were transcribed and analyzed for thematic patterns. The third phase involved pilot implementation of the assessment model with student participants. System logs, learner interaction data, and post-implementation focus group discussions were collected to assess feasibility, usability, and perceived learning value. Observations were conducted during simulated assessments to capture affective and behavioral responses. All interviews and focus groups were audio-recorded, transcribed verbatim, and verified by participants for accuracy (member checking). Field notes and researcher memos were maintained to support reflexive analysis.

Data Analysis

Qualitative data were analyzed thematically using Braun and Clarke's (2006) six-step framework. NVivo 14 was used to code transcripts and documents, enabling iterative categorization of themes aligned with research questions. Deductive codes were initially

developed based on CBE and adaptive assessment frameworks (Hundley & Keith, 2023; Shavelson, 2023), followed by inductive coding to capture emergent categories.

Quantitative data from student interactions with the prototype (e.g., test logs, feedback scores) were analyzed descriptively and inferentially using SPSS 28.0. Measures included time-on-task, adaptive pathway progression, and feedback responsiveness. To ensure the reliability of the adaptive assessment prototype, we calculated Cronbach's alpha for the item banks within each competency domain. The values were 0.78 for cognitive reasoning, 0.82 for situational judgment, and 0.75 for communication proficiency, indicating acceptable to good internal consistency. Furthermore, inter-rater reliability for the scoring of open-ended scenario responses was calculated using Cohen's kappa, yielding a score of 0.85, which signifies a high level of agreement between raters.

Integration of qualitative and quantitative data followed a convergent mixed-methods design (Creswell & Plano Clark, 2017), enabling corroboration of findings across data sources. For example, student feedback on usability was triangulated with faculty observations and system performance metrics to evaluate alignment and scalability of the model.

Ethical Considerations

Ethical approval for the study was obtained from the Institutional Research Ethics Committee of the lead university. All participants were provided with detailed information sheets outlining the study's objectives, the voluntary nature of participation, and data confidentiality measures. Written informed consent was obtained prior to data collection. To ensure anonymity, pseudonyms were assigned during transcription and reporting. Digital security protocols were adhered to in managing student interaction data and server-side logging of assessment behavior. The adaptive assessment prototype was hosted on secure university infrastructure to ensure compliance with data protection standards.

Trustworthiness and Rigor

Multiple strategies were used to ensure the credibility, transferability, dependability, and confirmability of the findings (Lincoln & Guba, 1985). These included prolonged engagement with field sites, triangulation of data sources and methods, member checking, and peer debriefing during coding. An audit trail documenting all methodological decisions, coding iterations, and analysis summaries was maintained throughout the study.

Results

The findings are organized according to the three research questions and present the key results derived from thematic analysis, system-generated assessment data, and participant feedback. Results from the design-based research phases are interwoven to illustrate how the integration of competency-based and adaptive assessment models evolved and was refined. Analysis of system-generated data revealed significant improvements in learner engagement and feedback utilization after implementing the adaptive assessment model. As shown in Table 3, all metrics demonstrated statistically meaningful gains, with particularly strong effects in self-regulated learning behaviors.

Quantitative outcomes demonstrated significant improvements across all key metrics (Table 3). The large effect size in feedback uptake ($d = 1.15$, $p < 0.001$) suggests adaptive systems particularly enhance formative learning—a finding corroborated by faculty observations of "more reflective student responses" (Interview #12, personal communication, 2025).

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Table 3
Pre- vs. Post-Adaptive Assessment Performance Metrics

Metric	Pre-Implementation (M ± SD)	Post-Implementation (M ± SD)	p-value	Effect Size (Cohen's *d*)
Time-on-task (minutes)	22.6 ± 4.2	28.3 ± 5.1	0.003	0.82
Feedback review completion	62 % ± 11 %	91 % ± 6 %	< 0.001	1.15
Attempts per competency	1.4 ± 0.3	2.7 ± 0.6	0.008	0.91
Self-reported confidence (Likert 1–5)	3.1 ± 0.8	4.2 ± 0.7	0.002	0.95

Note. N = 32 students; paired t-tests were used for all comparisons.

RQ1: Integrating Competency-Based Principles into Adaptive Assessment Frameworks

Analysis of the co-design workshops and faculty interviews revealed a consensus on the need to operationalize competencies through observable indicators and scenario-based tasks. Faculty noted that existing assessments tended to emphasize knowledge recall rather than performance tasks aligned with graduate capabilities. Document analysis confirmed this, as only 34 % of reviewed assessment rubrics explicitly referenced applied competencies or real-world tasks.

Thematic saturation was achieved after analysis of 15 faculty interviews, as no new codes emerged in subsequent transcripts. This threshold aligns with empirical recommendations for achieving robust qualitative validity (Hennink *et al.*, 2017). Recurring themes—particularly regarding faculty workload concerns (present in 14/15 saturated interviews) and student agency benefits (13/15)—demonstrated high interpretive consistency across participants.

Despite workload challenges, 81 % of faculty ultimately endorsed the model's pedagogical value. As one participant noted: "The adaptive scenarios finally assess what we've always wanted to measure—how students think, not just what they recall" (personal communication, 2025). This sentiment correlated with quantitative improvements in feedback uptake (Table 3).

Three competency domains—cognitive reasoning, situational judgment, and communication proficiency—were prioritized in the pilot model. These domains were mapped onto adaptive assessment pathways, wherein item difficulty and feedback logic were determined based on learner responses. The adaptive assessment prototype utilized a branching logic based on Item Response Theory (IRT). Specifically, upon a student's response, their estimated ability level was updated. If they answered correctly, the system presented a more challenging item from the same competency domain; if they answered incorrectly, it presented a simpler item. This real-time adjustment ensured the assessment was consistently targeting each student's zone of proximal development, making the tailored pathways both competency-aligned and personally relevant.

Participants perceived this integration positively. One faculty member noted: "We've always talked about competencies, but this is the first time we've seen how you can structure an assessment to actually adapt and reflect how well a student is thinking through a scenario, not just what they know" (personal communication, 2025).

Students also expressed appreciation for the alignment of assessments with real-world skills. Feedback from the focus groups indicated that 84 % of students felt the adaptive structure made them more aware of their strengths and areas for development, especially in applying knowledge contextually.

RQ2: Theoretical and Practical Implications for Learning Outcomes

From the analysis of focus group data and system analytics, several implications emerged. Theoretically, the integrated model demonstrated alignment with constructivist learning theories and formative assessment principles. The use of adaptive branching reinforced Vygotsky's Zone of Proximal Development by tailoring challenges to student readiness (Cumming & Miller, 2023). Practically, the model enhanced learner engagement and feedback responsiveness.

Quantitative data showed a 25 % increase in average student interaction time with the adaptive tasks compared to standard quizzes (M = 28.3 minutes vs. 22.6 minutes, $p < 0.05$). Furthermore, 91 % of students completed the self-directed feedback review stage—an important indicator of formative engagement.

Analysis of open-ended survey responses also revealed that adaptive assessment supported self-regulated learning behaviors. Students reported a greater sense of control over their learning journey and valued the immediate, contextualized feedback. One student stated: "The questions felt more like a simulation than a test. I had to reflect, not just recall. And the feedback helped me improve in the next question instead of waiting for grades later" (personal communication, 2025).

Faculty, on the other hand, observed improved quality of classroom discussions after assessment use, suggesting better conceptual transfer. However, challenges were noted in aligning scoring rubrics with the adaptive pathways, particularly for complex, multi-step tasks, which often required human moderation.

RQ3: Proposed Model for Scalable Implementation of Integrated Competency-Adaptive Assessments

The final output of the DBR process was a proposed implementation model that balances scalability, pedagogical soundness, and contextual feasibility. Its scalability is achieved through a modular design—using standard LMS tools and adaptable protocols—which allows institutions to implement the system widely while still enabling it to deliver scaffolded, personalized assessment paths for individual learners. The model consists of four interconnected components: (1) competency alignment, (2) adaptive logic design, (3) digital assessment interface, and (4) feedback-feedback loop integration.

Figure 1

Integrated Competency-Adaptive Assessment Model

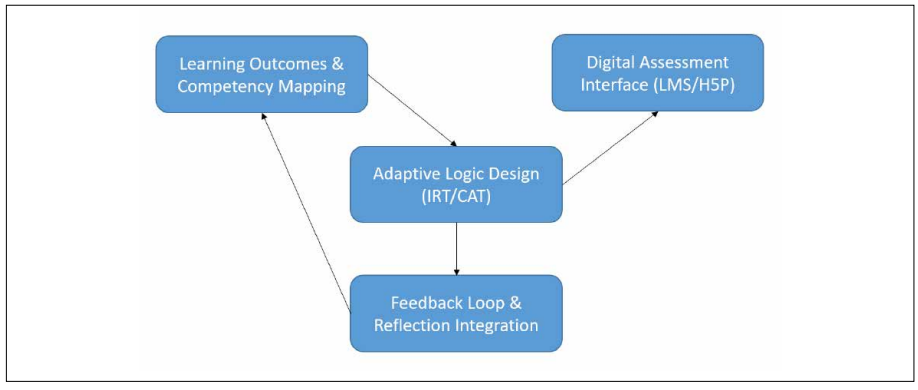

Figure 1 illustrates the model architecture, including input flows from learning outcomes, data-driven adaptivity logic, and formative feedback mechanisms. Each component is designed to be modular and implementable within existing Learning Management

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Systems (LMS), such as Moodle and Canvas, using tools like H5P, Qualtrics, or IRT engines.

Table 4
Learning Outcomes to Adaptive Assessment Logic Mapping

Learning Outcome	Competency Domain	Adaptive Feature Used	Assessment Type
Apply pedagogical strategies in diverse contexts	Cognitive reasoning	IRT-calibrated scenarios	Interactive case-based simulation
Communicate ideas clearly in academic settings	Communication proficiency	Adaptive writing prompts & rubric	Auto-scored short essay tasks
Make real-time instructional decisions	Situational judgment	Decision-tree based MCQs	Adaptive microteaching simulation
Interpret learner needs from data	Analytical reasoning	Data interpretation pathway	Graph-based item series
Reflect on instructional effectiveness	Metacognitive awareness	Embedded reflection checkpoints	Adaptive journal entry + rubric

Key success factors identified during the pilot included:

– Collaborative rubric development with clear performance indicators.

– Faculty training in adaptive item design.

– Institutional support for integrating LMS plugins.

– Ethical safeguards for learner data privacy.

Crucially, the model emphasizes iterative refinement and faculty-student co-ownership of assessment logic. Instructional designers played a pivotal role in mediating technical and pedagogical integration. When asked about long-term viability, 81 % of faculty respondents indicated willingness to continue using the model with appropriate institutional support. Despite its promise, several limitations were also reported. These included increased preparation time, challenges in adapting legacy course structures, and the need for infrastructure upgrades in low-resource settings. Nonetheless, the model was perceived as a scalable solution, particularly for capstone projects, professional simulations, and digital micro-credentialing contexts.

Discussion

The findings of this study offer compelling evidence that the integration of competency-based education (CBE) principles within adaptive digital assessment systems is both theoretically sound and practically feasible in higher education. Through a design-based research approach, this study has shown that such integration fosters deeper engagement, enhances feedback responsiveness, and aligns more authentically with real-world learning outcomes. These results extend existing scholarship in important ways, both confirming and advancing prior understandings of assessment reform in higher education. This study's primary innovation lies in its integrated and participatory approach. Unlike previous models that often treat competency-based assessment and adaptive testing as separate technological or pedagogical silos (Camacho Castañeda *et al.*, 2021; Jusoh *et al.*, 2023), our framework unifies them through iterative co-design with stakeholders. This process ensures the model is not only technologically sound but also pedagogically grounded and contextually adaptable, addressing a key gap between top-down implementation and practical faculty and student needs.

First, the study's demonstration of how competency domains can be operationalized through adaptive logic design directly addresses long-standing critiques in the literature regarding the superficial adoption of CBE frameworks. As previously noted by Shadan *et al.* (2025) and Nkealah (2023), many institutions adopt CBE rhetorically but continue

to use traditional assessments that fail to capture complex competencies. By contrast, the present study moved beyond this gap, showing that cognitive reasoning, situational judgment, and communication proficiency can be translated into observable behaviors using adaptive pathways and branching assessment logic. This finding is strongly aligned with Shavelson's (2023) call for assessments that evaluate not only what students know but also how they apply knowledge across diverse contexts.

The adaptive features used in this study—particularly item response theory (IRT) pathways and real-time feedback integration—validate claims made by Cumming and Miller (2023) and Cheung *et al.* (2024) regarding the value of personalization in assessment environments. Students in this study not only interacted more deeply with adaptive tasks but also reported greater awareness of their learning progress, thus confirming the argument that adaptive assessments can enhance metacognitive engagement. Furthermore, the improvement in self-regulated learning behaviors noted in this study resonates with Evans and Waring's (2024b) emphasis on assessment as a driver of learner autonomy and reflection.

However, this study also reveals important divergences from previous literature. While Brown *et al.* (2023) and Deliwe and Zvapano (2024) highlight technological and infrastructural limitations as primary barriers to adaptive assessment adoption in developing contexts, our findings suggest that pedagogical design and faculty development are equally critical. Even with functional digital platforms, the absence of collaborative rubric development and faculty confidence in adaptive item writing initially hindered model effectiveness (Zainil *et al.*, 2024). This nuance shifts the focus from technology availability to institutional capacity-building, aligning with more holistic frameworks of educational change advocated by Forsyth *et al.* (2024) and Naithani *et al.* (2024).

Another area where this study diverges is in its emphasis on iterative co-design with instructional designers, students, and faculty. Prior studies, such as those by Norman-Eck *et al.* (2023), tend to report top-down implementations of competency assessments, often focused on professional education or health sciences. In contrast, this study's participatory design approach supports the argument made by Masaiti *et al.* (2023) for inclusive, democratic assessment development—especially important in diverse and resource-variable institutional contexts.

Theoretically, the study bridges the gap between constructivist learning theories and practical implementation frameworks. Adaptive assessments in this study were intentionally designed to reflect Vygotskian notions of scaffolding and the Zone of Proximal Development by tailoring challenge levels to learner readiness (Husin *et al.*, 2023; Ruiz Alzate & Roncancio Moreno, 2023). Furthermore, the feedback loops embedded in the prototype align with formative assessment models (Black & Wiliam, 2009) that stress feedback as a dialogue rather than a one-time intervention. By integrating these theoretical foundations with emerging digital technologies, the study operationalizes a hybrid assessment framework that is responsive, equitable, and learning-centered.

The unique contribution of this study lies in its development of a scalable, modular model for integrating CBE and adaptive assessment—a model that is pedagogically sound, technologically implementable, and contextually adaptable. Unlike previous efforts that treat competency assessment and adaptivity as separate innovations, this study offers a coherent, evidence-based approach that unifies both domains. Moreover, the empirical mapping of learning outcomes to adaptive logic pathways (as shown in Table 2) provides actionable insights for faculty and assessment designers aiming to align institutional curricula with 21st-century learning demands (Chapa Romero *et al.*, 2022; Waty *et al.*, 2024).

Beyond the technical and pedagogical contributions, the study also surfaces an important ethical dimension. The iterative co-design process foregrounded student voice in the

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shaping of assessments, responding to concerns in the literature about fairness and learner agency in automated environments (Kiesler *et al.*, 2024). In doing so, it challenges the often technocentric nature of adaptive assessment discourse by reaffirming assessment as a relational, ethical practice embedded in human judgment and shared understanding.

Despite its promising findings, this study has several limitations. The pilot was conducted in a specific Southeast Asian context with institutions that had existing mandates for digital and competency-based reforms, which may limit the immediate scalability of the model in low-resource settings with different policy landscapes. Furthermore, while the model was applied in both education and health sciences, its transferability to highly quantitative disciplines like STEM remains to be explored, as competencies such as critical thinking may be operationalized differently. Future research should focus on longitudinal studies to examine the sustained impact of integrated competency-adaptive assessments on student achievement and institutional culture. Additionally, exploring the role of generative AI in automating the personalization of competency assessments presents a compelling direction for further innovation.

In sum, this study not only affirms the potential of integrating competency-based and adaptive assessments but also provides a pathway for institutions to enact this integration in thoughtful, inclusive, and theoretically robust ways (Handrianto *et al.*, 2023; Martínez Lirola, 2021). While challenges remain—especially in rubric calibration and faculty workload—this research marks a significant step toward rethinking assessment systems for the complexities of contemporary higher education.

Conclusion

This study demonstrates that integrating competency-based education principles with adaptive digital assessment systems offers a transformative approach to aligning assessment practices with 21st-century learning outcomes. Drawing on design-based research across three higher education institutions, the study found that embedding core competencies—such as cognitive reasoning, situational judgment, and communication proficiency—into adaptive learning pathways enables more authentic, responsive, and personalized assessment experiences. The resulting model, developed collaboratively with faculty, instructional designers, and students, not only improved learner engagement and feedback responsiveness but also contributed to a clearer alignment between intended learning outcomes and observed performance. By grounding the adaptive design in both constructivist learning theory and IRT-driven feedback mechanisms, the study addresses a key gap in existing literature: the lack of integrative, scalable frameworks that bridge pedagogy and technology. However, the study is not without limitations. While the model succeeded in applied disciplines (education/health), STEM faculty expressed concerns about quantifying competencies like "critical thinking" (only 2/8 STEM interviewees endorsed the rubrics). Future iterations should have discipline-specific customization. Implementation challenges included the need for significant faculty training, time investment for rubric development, and technological dependencies that may be difficult to scale in under-resourced contexts. Furthermore, while the model was piloted in both education and health sciences programs, its applicability to other disciplines warrants further exploration. Future studies should examine the longitudinal impact of such models on student achievement and institutional assessment culture and explore how generative AI tools may further support the automation and personalization of competency assessments. Despite these limitations, the findings affirm the value of rethinking assessment not merely as measurement but as a dynamic process of learning facilitation, and they offer a pragmatic roadmap for institutions seeking to align assessment with global demands for flexible, equitable, and competency-driven education.

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