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From Consumers to Creators: Transforming Teaching and Learning through Metaverse-Based Instruction for 21st-Century Competency Development

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Abstract. The rapid advancement of immersive technologies has intensified interest in the educational potential of the metaverse. However, existing research remains largely descriptive and provides limited empirical explanation of how metaverse-based instruction transforms teaching practices and learner roles. This study develops and empirically validates a Metaverse-Based Instruction (MBI) framework that explains how immersive instructional design facilitates the transition from learners as consumers to creators. Using a Design-Based Research approach, 11 secondary school teachers participated in a design-oriented professional development program and implemented metaverse-based lessons in authentic classroom settings. A mixed-methods analysis integrated quantitative assessments of teacher competencies with qualitative data from observations, artifacts, and focus groups. Findings indicate significant improvements in teachers' instructional design competencies, particularly in assessment integration and learner-centered design. Four levels of metaverse integration were identified: presentation, interaction, simulation, and transformative co-creation, with higher levels associated with increased learner agency, collaboration, and knowledge creation. Importantly, teacher perceptual shift emerged as a key mediating mechanism linking instructional design and learner transformation. The study contributes a mechanism-based, empirically grounded framework that advances immersive education toward pedagogically driven transformation.

Keywords: Metaverse-Based Instruction; Design-Based Research; Learner Agency; 21st-Century Competencies; Teacher Professional Development

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1. Introduction

The rapid advancement of immersive technologies has reignited global interest in the educational potential of the metaverse. Conceptualized as a persistent, shared virtual ecosystem, originally envisioned in early speculative literature (Stephenson, 1992), the metaverse integrates virtual reality, augmented reality, and networked digital infrastructures into spatially immersive environments (Dionisio et al., 2013; Mystakidis, 2022). In contrast to conventional online learning platforms, metaverse environments allow learners to manipulate virtual objects, co-construct artifacts, and interact synchronously within shared three-dimensional spaces. These affordances suggest possibilities for experiential, collaborative, and agency-driven learning (Dede, 2009; Mikropoulos & Natsis, 2011; Park & Kim, 2022; Sripan & Jeerapattanatorn, 2025).

Despite growing enthusiasm, much of the existing literature remains insufficiently theorized and empirically validated. Prior studies have predominantly focused on learner engagement, motivation, or technological affordances, rather than systematically examining how immersive instructional design transforms classroom roles and learning processes (Zhang et al., 2022; Radianti et al., 2020). Three critical gaps persist. First, there is a lack of iterative, design-based validation of metaverse-based instructional models in authentic classroom contexts. Second, few studies explicitly integrate immersive environments with 21st-century competency frameworks in a structured and measurable manner (OECD, 2018; World Economic Forum, 2020).

Third, the pedagogical mechanisms through which metaverse-based instruction shifts learners from passive consumers to active creators remain underexplored, particularly in secondary education settings. Without clearly articulated instructional mechanisms, immersive technologies risk reproducing traditional transmission-based instruction in virtual form (Dwivedi et al., 2022; Park & Kim, 2022). This highlights the need for a pedagogically grounded and empirically validated instructional framework that explains how immersive environments can support meaningful learning transformation.

Addressing these gaps, the present study adopts a Design-Based Research (DBR) approach to develop and refine a Metaverse-Based Instruction (MBI) model aligned with 21st-century competency development. Specifically, the study aims to (1) examine how participation in a metaverse-based professional development program influences teachers' instructional design competencies, (2) investigate how different levels of metaverse integration relate to shifts in learner roles from consumers to creators, and (3) explain the mediating mechanisms linking immersive instructional design to competency development.

By doing so, this study contributes a mechanism-based and empirically grounded instructional framework that advances immersive education beyond technological affordances toward pedagogically driven transformation.
The study is guided by three research questions:

1. How does participation in a metaverse-based professional development program influence teachers' instructional design competency?

2. How do different levels of metaverse integration relate to shifts in learner roles from consumers to creators?
3. What mediating mechanisms explain the relationship between immersive instructional design and 21st-century competency development?

By empirically examining these questions through iterative Design-Based Research cycles, this study contributes a validated instructional framework and a mechanism-based explanation of how immersive environments can support transformative teaching and learning. In doing so, it advances the discourse on immersive education beyond technological affordances toward pedagogically grounded transformation.

2. Literature Review

2.1 Metaverse as an Evolving Educational Paradigm

The metaverse represents a continuation rather than the sudden emergence of immersive virtual learning environments. Earlier platforms such as Second Life and Mozilla Hubs have long enabled users to interact through avatars, co-construct digital artifacts, and participate in synchronous virtual communities (Dionisio et al., 2013; Mikropoulos & Natsis, 2011). These virtual worlds laid the pedagogical and technological foundations for what is now conceptualized as the metaverse. Recent scholarship extends this lineage by emphasizing the convergence of virtual reality (VR), augmented reality (AR), artificial intelligence, and networked social infrastructures into persistent and immersive ecosystems (Dwivedi et al., 2022; Park & Kim, 2022; Tlili et al., 2023; Lee et al., 2021). In educational contexts, the metaverse is increasingly framed as an evolution of digital learning environments that enables spatial interaction, simulation-based learning, and collaborative knowledge construction beyond traditional learning management systems.

However, despite these advances, empirical evidence remains uneven. While studies consistently report increased engagement and motivation, fewer investigations examine how instructional design within immersive environments leads to meaningful pedagogical transformation. Moreover, emerging research cautions that without pedagogical alignment, immersive technologies may replicate traditional transmission-based instruction in more visually sophisticated forms (Radianti et al., 2020; Dwivedi et al., 2022).

2.2 Constructivism, Experiential Learning, and Instructional Design in Immersive Environments

Constructivist theory posits that learning occurs through active knowledge construction rather than passive reception (Piaget, 1972; Jonassen, 1999). In immersive environments, this perspective implies that learners should engage in meaningful tasks involving exploration, manipulation, and collaborative problem-solving. Jonassen (1999) further emphasizes the importance of authentic tasks, multiple representations, and social negotiation in designing constructivist learning environments.

Experiential learning theory (Kolb, 1984) provides a complementary lens by conceptualizing learning as a cyclical process involving concrete experience, reflective observation, abstract conceptualization, and active experimentation. Immersive environments are particularly well-suited to support this cycle, as they allow learners to engage in simulated experiences, reflect on their actions, and iteratively refine their understanding within dynamic virtual contexts. However, prior research rarely explicates how these theoretical principles are operationalized within metaverse-based instructional design. In many cases, immersive environments are used to enhance presentation or interaction without systematically structuring learning experiences according to constructivist or experiential principles. This highlights the need for instructional models that explicitly translate learning theory into design principles within immersive environments.

2.3 21st-Century Competencies and Entrepreneurial Mindset Development

Global educational policy frameworks consistently emphasize the need to cultivate competencies that extend beyond disciplinary knowledge. The OECD Education 2030 framework identifies key competencies such as critical thinking, collaboration, self-regulation, and acting autonomously in complex contexts (OECD, 2018). Similarly, the World Economic Forum (2020) underscores creativity, problem-solving, resilience, and digital literacy as foundational capabilities for navigating rapidly evolving labor markets. These competencies intersect with the concept of entrepreneurial mindset, which encompasses opportunity recognition, innovative thinking, risk management, and proactive problem-solving (Kuratko, 2016).

Research in entrepreneurship education indicates that experiential, project-based, and simulation-driven pedagogies are particularly effective in fostering entrepreneurial competencies (Neck & Greene, 2011; Nabi et al., 2017; World Economic Forum, 2020). Immersive digital platforms offer promising affordances for embedding such competencies within authentic learning scenarios. Similarly, talent-based educational approaches have been shown to enhance students' motivation, self-confidence, and social skills by aligning learning with individual interests and potentials (Taufikin & Nurhayati, 2026).

By enabling learners to design virtual products, simulate business contexts, and collaborate in co-created spaces, metaverse-based instruction may serve as a bridge between academic knowledge and real-world application (Dwivedi et al., 2022; Zhang et al., 2022). However, few empirical studies have systematically examined how immersive instructional design models explicitly integrate entrepreneurial and well-being competencies within secondary education settings.

2.4 Teacher Professional Development and Instructional Transformation

The integration of immersive technologies in education is fundamentally mediated by teachers' pedagogical capacity. Research consistently demonstrates that technological innovation leads to meaningful learning outcomes only when accompanied by instructional redesign (Ertmer & Newby, 2013; Reiser & Dempsey, 2017). In immersive contexts, teachers are required to shift from content transmitters to facilitators of inquiry, designers of learning environments, and co-learners within virtual spaces. Recent studies on immersive teacher training report increased confidence and willingness to experiment with learner-centered approaches (Radianti et al., 2020; Hernández Cárdenas et al., 2024). However, significant challenges remain, including limited pedagogical guidance, difficulties in assessment design, and uncertainty regarding how to align immersive affordances with curriculum goals (Park & Kim, 2022; Tlili et al., 2023).

These findings suggest that professional development must move beyond technical training toward design-oriented approaches that support teachers in translating immersive affordances into structured pedagogical practices. Without such support, immersive technologies risk being underutilized or misaligned with learning objectives.

2.5 Design-Based Research as a Methodological Framework for Innovation

Design-Based Research (DBR) has emerged as a methodological approach for developing and refining educational innovations in authentic contexts. Unlike experimental designs that isolate variables under controlled conditions, DBR emphasizes iterative cycles of design, implementation, analysis, and redesign to generate both practical solutions and theoretical contributions (Brown, 1992; Collins et al., 2004). The approach is particularly suited to complex technological interventions where pedagogy and context co-evolve (Reiser & Dempsey, 2017). In the field of educational technology, DBR has been employed to develop learning analytics systems, immersive simulations, and collaborative digital platforms (Radianti et al., 2020; Dwivedi et al., 2022).

By situating innovation within real classrooms, DBR enables researchers to identify emergent design principles grounded in practice rather than abstraction. Given the rapidly evolving nature of metaverse technologies, DBR provides a rigorous yet flexible framework for aligning technological affordances with competency-driven instructional goals. However, there remains a need for empirically grounded metaverse-based instructional models validated through iterative classroom implementation and teacher collaboration.

3. Methodology

3.1 Research Design

This study employed a Design-Based Research (DBR) methodology to iteratively design, implement, analyse, and refine a Metaverse-Based Instruction (MBI) model aimed at fostering 21st-century competency development. DBR was selected because it allows researchers to develop theoretically grounded instructional innovations within authentic educational settings while simultaneously generating practical design principles (Brown, 1992; Collins et al., 2004).

Unlike controlled experimental designs, DBR emphasizes ecological validity, iterative refinement, and the co-evolution of theory and practice (Design-Based Research Collective, 2003). The present study followed four iterative DBR phases: (1) Design, (2) Implementation, (3) Analysis, and (4) Refinement. These phases were conducted over a one-year period in a secondary school context and involved close collaboration between researchers and participating teachers.

3.2 Phase 1: Design of the Metaverse-Based Instruction (MBI) Model

A two-day intensive professional development workshop was designed as an initial entry point rather than a complete training intervention. The workshop focused on foundational competencies, including immersive space creation, interactive task design, competency-oriented assessment, and alignment of metaverse activities with subject-specific learning objectives.

Importantly, the workshop was followed by sustained, iterative support throughout the implementation phase. Teachers engaged in guided lesson design activities, received feedback from the research team, and participated in ongoing consultation sessions. This extended support structure enabled teachers to progressively refine their instructional designs beyond the initial training period, consistent with the iterative nature of Design-Based Research.

Thus, the professional development model combined short-term intensive training with continuous scaffolding, allowing teachers to develop both technical proficiency and pedagogical integration over time.

3.3 Phase 2: Implementation in Authentic Classroom Contexts

Following the workshop, teachers independently developed metaverse-based lesson plans aligned with their subject curricula. While teachers maintained primary responsibility for instructional design, the research team provided structured consultation and formative feedback throughout the implementation phase. This support included reviewing lesson plans, suggesting design refinements, and facilitating reflective discussions. Each teacher implemented at least one MBI lesson using Spatial.io over a three-month period. Although researcher support was present, instructional decisions remained teacher-driven, ensuring that the implementation reflected authentic classroom practices rather than researcher-controlled intervention.

To account for variation across subject domains, teachers were encouraged to adapt the MBI framework to their disciplinary contexts. This resulted in differentiated implementations, which were subsequently analysed to examine patterns of instructional transformation across subjects.

3.4 Phase 3: Data Analysis

A mixed-methods analytical approach was used to examine both teacher transformation and instructional outcomes.

3.4.1 Quantitative Analysis

Teacher competency development was measured using a 20-item assessment instrument covering four domains: platform functionality, instructional design, assessment integration, and subject-level application. The instrument was developed based on existing instructional design and technology integration frameworks adapted from TPACK and prior studies. To enhance validity, the instrument was reviewed by three experts in educational technology and instructional design and pilot-tested prior to data collection. Internal consistency reliability was assessed using Cronbach's alpha (α = 0.88), indicating acceptable reliability. The assessment combined self-reported ratings with rubric-based evaluation of lesson design artifacts to mitigate potential self-report bias. Paired-sample t-tests were conducted to examine pre–post differences, and effect sizes (Cohen's d) were calculated to determine practical significance.

3.4.2 Qualitative Analysis

Qualitative data were collected from multiple sources, including lesson plan artifacts, classroom observations, teacher reflective journals, and student-generated artifacts within virtual environments. In addition, focus group discussions were conducted with participating teachers to capture perceptions of learner engagement, role transformation, and competency development. Student-level evidence was derived from analysis of learning artifacts (e.g., virtual spaces, collaborative outputs), observational field notes, and selected student reflections. These data were used to triangulate teacher-reported outcomes and provide illustrative evidence of learner role transformation.

Data were analysed using thematic content analysis (Braun & Clarke, 2006). Coding focused on identifying patterns related to instructional design, levels of metaverse integration, learner roles, and competency manifestations. Inter-rater reliability was established using Cohen's kappa (κ = .87).

3.4.3 Phase 4: Iterative Refinement and Model Validation

The Design-Based Research process involved iterative cycles of design, implementation, analysis, and refinement. Rather than a single post-hoc validation, the MBI framework evolved through continuous feedback across implementation phases. Insights from early lesson implementations informed subsequent instructional redesign, particularly in increasing the use of co-creation tasks and embedding competency-oriented assessment. Teacher reflections and classroom observations played a critical role in identifying design limitations and refining instructional strategies.

The final MBI framework therefore represents a synthesis of multiple iterations, integrating both quantitative improvements in teacher competencies and qualitative evidence of learner transformation. This iterative refinement process strengthens the ecological validity and practical applicability of the proposed model.

3.5 Participants and Context

The study was conducted in a public secondary school in Thailand. Participants included 11 in-service teachers (7 female, 4 male) with teaching experience ranging from 3 to 25 years. Subjects represented included physics, biology, chemistry, technology, mathematics, Thai language, English language, and business studies. Student participants were approximately 420 secondary school students across Grades 10–12 who experienced the implemented MBI lessons. Ethical approval was obtained from the university Institutional Review Board prior to data collection (KUREC-SSR68/111). All participants provided informed consent, and data were anonymized to ensure confidentiality.

3.6 Trustworthiness and Validity

To enhance methodological rigor, the study employed triangulation across quantitative assessments, artifact analysis, observations, and reflective data. Member checking was conducted during focus group sessions to confirm interpretive accuracy. Inter-rater reliability procedures strengthened the validity of qualitative coding. The iterative DBR process further enhanced internal validity by allowing continuous refinement of instructional design principles based on empirical evidence.

4. Results

This section presents the findings of the Design-Based Research (DBR) process, organized according to the three research questions. Quantitative and qualitative data are integrated to provide a comprehensive explanation of how Metaverse-Based Instruction (MBI) facilitates the transformation of learners from consumers to creators. The presentation follows a logical sequence from teacher development to instructional integration, to learner transformation, and finally to the underlying mechanisms.

4.1 Influence of Metaverse-Based Professional Development on Teachers' Instructional Design Competencies (RQ1)

To address RQ1, pre- and post-intervention assessments were conducted across four domains: platform functionality, instructional design, assessment integration, and subject-level application.

Table 1: Descriptive Statistics of Teacher Competency Scores (Pre–Post)

Domain	Pretest		Post-test		Mean Difference	t-value	p-value	Cohen's d
	Mean	SD	Mean	SD				
Platform Functionality	3.55	.82	4.82	.40	1.27	4.91	< .001	1.48
Instructional Design	3.18	.94	4.27	.65	1.09	4.12	< .001	1.24
Assessment Integration	2.64	1.02	4.18	.75	1.54	5.37	< .001	1.62
Subject-Level Application	2.91	.88	3.82	.84	.91	3.44	.006	1.04
Total (20 pts)	12.27	2.51	17.09	2.38	4.82	6.02	< .001	1.81

Results indicated statistically significant improvements across all domains ($p < .01$), with a large overall effect size (Cohen's $d = 1.81$). The most substantial gains were observed in assessment integration and instructional design, suggesting that teachers progressed beyond technical proficiency toward competency-oriented pedagogical design.

Qualitative findings further substantiate these improvements by revealing a shift in teachers' instructional perspectives. Teachers reported moving from lecture-based instruction toward more interactive and participatory approaches. For example, one teacher reflected:

"I have changed my teaching mindset. When students actively participate in activities, they become much more engaged in learning." (Teacher, Focus Group)

This shift indicates that professional development influenced not only technical skills but also pedagogical beliefs and practices. In addition, teachers demonstrated an increased ability to embed assessment within immersive learning activities. Rather than relying solely on teacher-centered evaluation, they incorporated peer feedback and collaborative assessment processes. One teacher explained:

"Students were able to review and critique each other's work, rather than relying only on teacher evaluation." (Teacher, Focus Group)

These findings suggest that teachers developed the capacity to design learning environments that integrate assessment, collaboration, and learner agency. Overall, the results provide strong evidence that participation in the metaverse-based professional development program significantly enhanced teachers' instructional design competencies, thereby establishing the foundation for subsequent instructional transformation.

4.2 Levels of Metaverse Integration and Learner Role Transformation (RQ2)

To address RQ2, artifact analysis of lesson plans identified four levels of metaverse integration: presentation, interaction, simulation, and transformative co-creation.

Table 2: Distribution of Lesson Plans by Metaverse Integration Level

Integration Level	Description	N	%
Level 1 – Presentation	Virtual space used for content display only	3	27%
Level 2 – Interaction	Students engage in structured interaction tasks	2	18%
Level 3 – Simulation	Problem-based or experiential virtual scenarios	3	27%
Level 4 – Transformative Co-creation	Student-generated immersive spaces and artifacts	3	27%

The analysis revealed a clear progression in learner roles across these levels. At the presentation level, learners primarily engaged as passive recipients of content. At the interaction level, they participated in structured activities within teacher-defined boundaries. At the simulation level, learners engaged in contextualized problem-solving tasks. At the highest level, transformative co-creation, learners actively designed virtual environments and generated knowledge artifacts. This progression is further illustrated through subject-based distribution patterns.

	1	2	3	4
Science & Technology		T05	T04 T06	T01 T02 T03
Mathematics			T10	
Career Education		T07		
Thai Language	T08 T09			
English Language	T11			

Level of Integration

Figure 1: Distribution of Metaverse Integration Levels Across Subject Domains

As shown in Figure 1, science and technology subjects demonstrated deeper levels of integration, while language subjects tended to remain at lower levels. These patterns suggest that disciplinary epistemologies influence the extent of immersive integration. Qualitative findings provide further insight into how these structural differences translated into learner role transformation. At higher levels of integration, students engaged in collaborative knowledge construction and distributed task responsibilities. One teacher described:

> *"Students divided tasks among themselves – some focused-on design, while others collaborated to complete the work."* (Teacher, Focus Group)

This reflects a shift from individual task completion to collaborative production. Students also demonstrated increased engagement and intrinsic motivation. Teachers observed that learners continued working beyond classroom hours:

> *"Students stayed until 6 p.m. every day because they enjoyed the activities and wanted to continue working."* (Teacher, Focus Group)

At the transformative co-creation level, learners assumed ownership of their learning environments by designing virtual spaces and producing original artifacts. This sense of ownership was evident in how students related to the virtual spaces they created. As one teacher noted:

> *"Students felt that this was their own space – their own room – so they wanted to come back and improve it, just like their own home."* (Teacher, Focus Group)

This reflects a deeper shift from task completion toward ownership-driven learning, where learners not only participate in activities but also take responsibility for shaping and extending their learning environments.

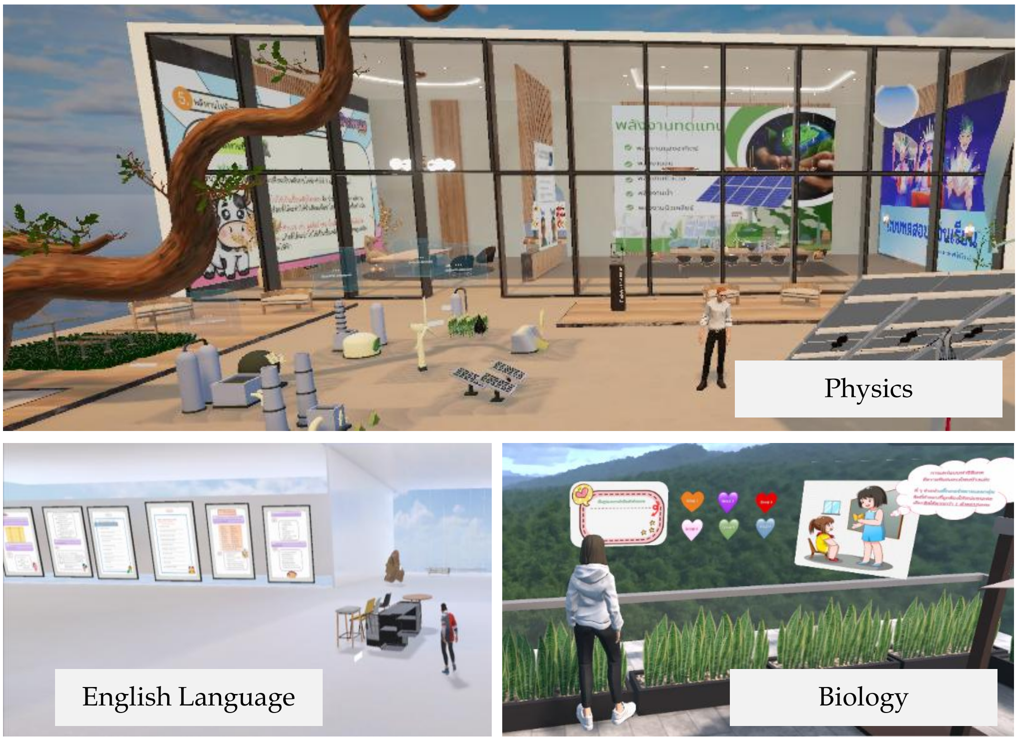

Figure 2: Empirical artifacts of immersive instructional design across disciplinary contexts

As illustrated in Figure 2, higher levels of integration are characterized not merely by visual complexity but by the redistribution of epistemic authority. Students move from navigating predefined content to constructing and curating their own learning environments. One teacher noted:

> *"Students designed their own virtual rooms and continued working collaboratively as a team."* (Teacher, Focus Group)

These findings indicate that learner role transformation is strongly associated with the depth of instructional integration rather than the presence of immersive technology alone.

4.3 Teacher Perceptual Shifts as a Mediating Mechanism (RQ3)

To address RQ3, qualitative analysis was conducted to identify the mechanisms linking immersive instructional design and learner competency development. Findings indicate that teacher perceptual shifts function as a critical mediating mechanism in the transformation process. While structural integration provides opportunities for change, transformation occurs through how teachers interpret and enact these opportunities.

Three interrelated perceptual shifts emerged. First, teachers redistributed instructional control by shifting from directive teaching toward facilitative guidance. Second, they recognized previously underutilized learner capabilities. Third, they reframed assessment as an embedded component of learning activities.

A key insight from the data is the reversal of traditional teacher–student roles. One teacher reflected:

> *"Even though I was not skilled in this area, students helped me, and we learned together."* (Teacher, Focus Group)

This illustrates a shift toward co-learning and shared authority within the classroom. These perceptual changes influenced subsequent instructional design decisions. Teachers began to intentionally incorporate open-ended, student-driven tasks that emphasized creativity, collaboration, and problem-solving.

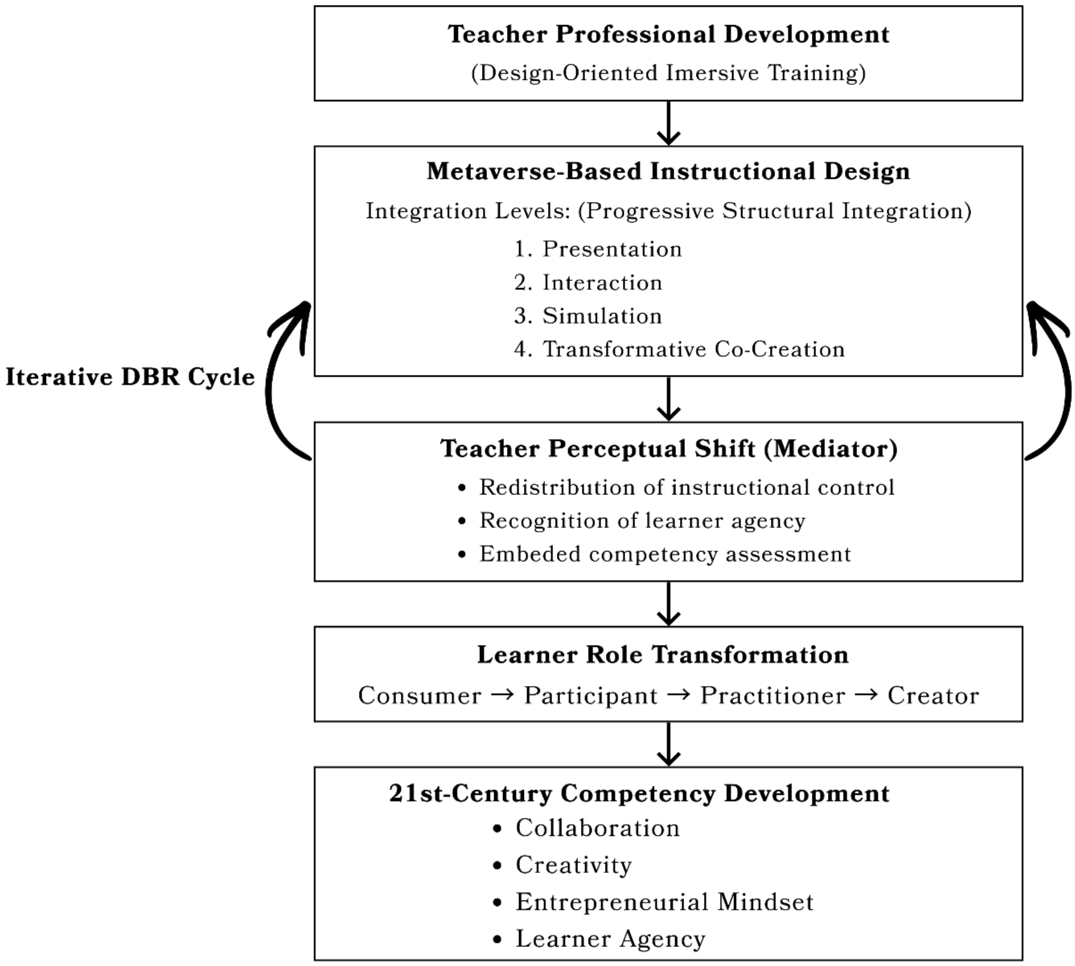

Figure 3: Mechanism model of Metaverse-Based Instructional (MBI) transformation

As illustrated in Figure 3, teacher professional development influences instructional design, which affects learner roles through teacher perceptual shifts as a mediating mechanism. This process operates iteratively, consistent with the DBR framework. Importantly, this iterative dynamic highlight that instructional transformation is not linear but co-evolves through continuous interaction between teacher cognition and classroom practice.

4.4 Integrated Mechanism of Instructional Transformation

Synthesizing findings across RQ1–RQ3, the results support a mechanism-based model of instructional transformation. Teacher professional development enhances instructional design competencies, enabling deeper levels of metaverse integration. As integration progresses, learner roles shift from passive consumption to active participation and ultimately to knowledge creation. However, this transformation is not linear or automatic. It is mediated by teacher perceptual shifts, which shape how instructional designs are implemented and refined.

Qualitative evidence indicates that when learners are given ownership of immersive environments, they develop a strong sense of agency, collaboration, and responsibility for learning. Students do not merely complete assigned tasks but actively construct knowledge, negotiate meaning, and extend learning beyond classroom boundaries. The DBR process further reveals that instructional transformation is iterative. Teacher perceptions and instructional practices co-evolve through cycles of design, implementation, and refinement. Overall, the findings provide empirical support for a validated MBI framework in which teacher development, instructional design, learner roles, and competency outcomes are dynamically interconnected. This mechanism-based explanation advances understanding of how immersive environments can support meaningful pedagogical transformation in secondary education.

5. Discussion

This study sets out to explain how metaverse-based instruction can move beyond technological novelty to support meaningful pedagogical transformation. By integrating quantitative and qualitative findings, the results provide a mechanism-based explanation of how immersive instructional design facilitates the transition from learners as consumers to learners as creators. The discussion is organized according to the three research questions, followed by implications and limitations.

5.1 Teacher Competency Development as a Foundation for Instructional Transformation (RQ1)

The findings demonstrate that participation in a metaverse-based professional development program significantly enhanced teachers' instructional design competencies across multiple domains. Importantly, this development extended beyond technical proficiency to include pedagogical redesign and assessment integration. This result aligns with prior research emphasizing that technological innovation alone does not lead to meaningful learning outcomes unless accompanied by instructional transformation (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2020). In immersive learning contexts, teachers must develop not only technological knowledge but also the capacity to design learning experiences that leverage these affordances effectively (Radianti et al., 2020; Tlili et al., 2023).

The present study extends this body of work by providing empirical evidence that design-oriented professional development can act as a catalyst for such transformation. Rather than focusing solely on tool usage, the professional development model emphasized iterative design, implementation, and reflection. This aligns with recent calls for practice-based and design-centered teacher learning approaches in educational technology integration (Philipsen et al., 2019; Voogt et al., 2022). Furthermore, the substantial gains observed in assessment integration suggest a shift toward competency-oriented pedagogy.

This finding is particularly significant given that assessment remains one of the most challenging aspects of technology integration (Bower, 2019). By embedding assessment within immersive activities, teachers moved toward more authentic and performance-based evaluation practices, consistent with contemporary competency frameworks (OECD, 2018; World Economic Forum, 2020). Taken together, these findings suggest that teacher competency development functions as a necessary precondition for immersive instructional transformation. Without such development, immersive technologies are likely to be used at superficial levels, limiting their pedagogical impact.

5.2 Learner Role Transformation and the Structural Conditions of Immersive Learning (RQ2)

The findings reveal a clear progression in learner roles from passive recipients to active creators, contingent upon the level of metaverse integration. This progression provides empirical support for constructivist and experiential learning theories, which posit that knowledge is actively constructed through engagement, interaction, and reflection (Piaget, 1972; Kolb, 1984; Jonassen, 1999). At lower levels of integration, learners remained primarily consumers of content, despite the presence of immersive technology. This finding reinforces recent critiques that immersive environments may replicate traditional transmission-based pedagogy if not supported by appropriate instructional design (Dwivedi et al., 2022; Makransky & Petersen, 2021).

In contrast, higher levels of integration, particularly simulation and transformative co-creation, enabled learners to engage in authentic problem-solving, collaborative knowledge construction, and artifact creation. These findings are consistent with emerging research on immersive learning environments, which highlights the importance of active participation and learner agency in achieving meaningful outcomes (Makransky et al., 2019; Radianti et al., 2020; Kye et al., 2021). A key contribution of this study lies in identifying the structural conditions under which learner transformation occurs. Specifically, the results demonstrate that learner-generated artifacts, collaborative task design, and open-ended problem spaces are critical drivers of agency and higher-order thinking. This extends prior research by moving beyond general claims about engagement to specify the instructional design features that enable transformation.

Moreover, the observed increase in intrinsic motivation and sustained engagement aligns with self-determination theory, which emphasizes autonomy, competence, and relatedness as key drivers of motivation (Ryan & Deci, 2020). By allowing learners to design their own virtual environments and take ownership of learning tasks, immersive instruction created conditions that support these psychological needs. Importantly, these findings suggest that immersive technology alone does not transform learning. Rather, transformation is structurally contingent upon how instructional tasks are designed and implemented. This distinction is critical for advancing the field beyond technological determinism toward pedagogically grounded innovation.

5.3 Teacher Perceptual Shift as a Mediating Mechanism (RQ3)
One of the most significant contributions of this study is the identification of teacher perceptual shift as a mediating mechanism linking instructional design and learner transformation. While previous studies have acknowledged the importance of teacher beliefs in technology integration (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2020), few have empirically demonstrated how these beliefs function within immersive learning contexts. These findings align with recent research highlighting how emerging technologies, including artificial intelligence, are reshaping teacher roles toward facilitation and adaptive pedagogy (Taufikin et al., 2024).

The present findings address this gap by showing that changes in teacher perception directly influence how immersive environments are enacted in practice. Specifically, three interrelated shifts were identified: redistribution of instructional control, recognition of learner agency, and reframing of assessment. These shifts enabled teachers to move from directive teaching toward facilitative and co-learning roles. This mechanism can be conceptualized as a dynamic process in which professional development initiates change in teacher cognition, which in turn shape instructional design and ultimately influence learner outcomes.

This perspective aligns with TPACK theory (Koehler & Mishra, 2009) and extends it by specifying the mediating role of teacher perception in immersive contexts. Furthermore, the findings resonate with recent research on teacher agency and adaptive expertise, which emphasizes the importance of reflective and flexible teaching practices in complex learning environments (Priestley et al., 2015; Voogt et al., 2022).

A particularly noteworthy insight is the reversal of traditional teacher–student roles, where students contribute to the learning process and even support teachers in navigating technological environments. This shift reflects a move toward participatory and distributed models of knowledge construction, consistent with sociocultural learning theory (Vygotsky, 1978) and contemporary perspectives on collaborative learning (Sawyer, 2014).

Importantly, the findings demonstrate that without such perceptual shifts, immersive environments are likely to remain at lower levels of integration. Thus, teacher cognition is not merely a contextual factor but a central mechanism driving instructional transformation.

5.4 Theoretical and Practical Implications

This study makes several important contributions to the field of immersive education. First, it advances the literature by proposing a mechanism-based framework that explains how immersive instructional design leads to learner transformation. Unlike prior studies that focus on technological affordances, this research identifies the interaction between teacher development, instructional design, and learner roles as the core driver of transformation. Second, it conceptualizes metaverse integration as a progressive continuum, providing a structured pathway from presentation to transformative co-creation.

This framework offers both theoretical clarity and practical guidance for educators seeking to implement immersive learning. Third, the identification of teacher perceptual shift as a mediating mechanism provides a novel contribution to research on technology integration. This insight bridges the gap between teacher cognition and instructional practice, offering a more comprehensive understanding of how pedagogical change occurs.

From a practical perspective, the findings highlight the importance of design-oriented professional development that supports teachers in translating immersive affordances into pedagogically meaningful practices. Additionally, the results suggest that instructional design should prioritize learner-generated artifacts, collaboration, and embedded assessment to maximize the transformative potential of immersive environments.

5.5 Limitations and Future Research

Despite its contributions, this study has several limitations. First, the research was conducted within a single institutional context, which may limit the generalizability of the findings. Future studies should examine the applicability of the MBI framework across diverse educational settings and cultural contexts. Second, the duration of the intervention was relatively limited. Longitudinal research is needed to investigate the sustainability of teacher transformation and learner outcomes over time. Third, the study focused on a specific metaverse platform. Given the rapid evolution of immersive technologies, future research should explore cross-platform implementation and comparative effectiveness. Finally, while this study provides strong evidence of learner transformation, further research is needed to examine long-term impacts on academic achievement and transferable competencies.

6. Conclusion

This study examined how metaverse-based instruction can move beyond technological novelty to support meaningful pedagogical transformation. Using a Design-Based Research approach, it developed and refined a Metaverse-Based Instruction (MBI) framework that explains how immersive instructional design facilitates the transition from learners as consumers to learners as creators. The findings demonstrate that such transformation is not driven by immersive technology alone. Instead, it emerges through a mechanism-based process linking teacher professional development, progressive levels of instructional integration, and teacher perceptual shift. As teachers redesign learning environments and redistribute instructional authority, learners increasingly assume active roles in knowledge construction, leading to the development of collaboration, creativity, learner agency, and entrepreneurial competencies.

Importantly, the study identifies teacher perceptual shift as the critical mediating mechanism that enables this transformation. Without such a shift, immersive environments are likely to remain at surface levels of integration and fail to produce meaningful changes in learner roles. The study contributes a validated, mechanism-based, and subject-sensitive instructional framework that advances immersive education from a focus on technological affordances toward pedagogically grounded transformation.

By explicating how instructional design, teacher cognition, and learner roles interact, the MBI framework provides both a theoretical model and a practical pathway for implementing competency-oriented immersive learning in secondary education. Overall, this research highlights that the transformative potential of the metaverse lies not in the technology itself, but in the intentional design of learning environments that empower learners as creators of knowledge.

Conflict of Interest
The authors declare that there is no conflict of interest regarding the publication of this paper.

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