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Enhancing Learning Achievement through GenAI Assisted Collaborative Drama-Based Role-Play Learning Metaverse in Higher Education

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Abstract: Cultivating real-world problem-solving, decision-making, communication, professional identity (PI), and workplace-related skills in higher education is crucial for preparing students for career readiness, yet conventional project-based learning (PBL) often lacks authentic, immersive learning contexts that foster deep engagement and learning achievement development. Addressing this gap, we designed a novel Learning Metaverse environment enhanced with assistive Generative AI (GenAI) agents, grounded in Self-Determination Theory (SDT) and Identity-Based Motivation (IBM) Theory. This approach enables students to create personalized 3D avatars through large language models (LLMs) by communicating verbally and non-verbally, using the Ready Player Me platform to map their facial features through 2D images and customize their PI, while engaging in collaborative, drama-based role-play learning activities based on a drama script related to the textbook content, assisted by real-time GenAI feedback. In a quasi-experimental study within a Taiwanese university's hospitality management program, two cohorts participated in drama-based role-play simulating Japanese restaurant workplace culture: the experimental group (n=34) used the GenAI assisted learning metaverse with avatar customization for better PI, while the control group (n=32) used a conventional metaverse with limited predesigned selective avatar options and no GenAI feedback. Results demonstrated that the GenAI-assisted learning metaverse significantly enhanced learning achievement, engagement, and key dimensions of PI, including responsibility, self-identity, accountability, self-efficacy, and belongingness. These findings underscore the efficacy of integrating metaverse and GenAI technologies to create immersive, contextually rich educational environments. Implications include providing students with authentic opportunities for PI construction and skill development, offering educators actionable frameworks for technology-enhanced learning design, and informing policymakers on the value of investing in robust, theory-driven digital learning infrastructures to improve graduate employability and lifelong learning outcomes.

Keywords: Collaborative learning, Metaverse, Interactive learning environments, Drama-based learning, GenAI-supported scaffolding

1. Introduction

The rapid advancement of digital technologies is reshaping higher education by creating new ways to develop essential career skills like problem-solving, decision-making, communication, and PI. Among these, the metaverse, a 3D environment enabling real-time interaction and digital identity, stands out as a promising educational innovation (Barry &

Kanematsu, 2025; Gim et al., 2023). The metaverse allows learners to transcend the limitations of physical classrooms, enabling authentic, multisensory, and context-rich experiences that closely mirror real-world professional environments (Zhang et al., 2022). While PBL (Han & Bhattacharya, 2002) provides authentic learning, metaverse environments enhance this by providing embodied, immersive experiences that simulate professional scenarios. (Zhang et al., 2022). However, a critical research gap remains on how learning metaverse combined with advanced Artificial Intelligence (AI) and grounded in motivation and identity theories can effectively promote deep engagement, learning achievement, and PI development.

Self-Determination Theory (SDT) posits that the satisfaction of students' basic psychological needs for autonomy, competence, and relatedness is fundamental for promoting intrinsic motivation, sustained engagement, and effective learning (Deci & Ryan, 2000). Complementing this, Identity-Based Motivation (IBM) theory highlights that students are more likely to engage in and persist with learning activities when these activities are perceived as congruent with their salient identities, and when they view challenges as meaningful instead of impossible to overcome. (Oyserman & Destin, 2010). In higher education, the development of a strong PI is increasingly recognized as a key factor in students' confidence, self-efficacy, goal setting, and employability, as well as their ability to navigate complex workplace environments (Tan et al., 2017; Tomlinson & Jackson, 2019).

Concurrently, the integration of AI technologies such as Chatbots or GenAI agents, intelligent tutoring systems, and real-time analytics has shown significant potential to personalize learning, provide adaptive feedback, and support students' cognitive and affective needs(Vázquez-Cano et al., 2021). Yet, empirical research into the combined impact of these technologies within immersive metaverse environments, particularly on students' PI creation and engagement in learning, remains limited. Addressing this gap, this study presents a novel Learning Metaverse environment enhanced with assistive GenAI agents. This environment empowers students to create and embody personalized 3D avatars by mapping their facial features through 2D images of their own face, selecting a gender, and customizing their digital identity, while participating in collaborative, drama-based role-play learning activities that simulate authentic workplace scenarios. Real-time GenAI feedback further supports students' autonomy, competence, and relatedness, while fostering identity-congruent experiences that underpin deep engagement and PI development.

This research is guided by two primary objectives: first, to examine whether the GenAI-assisted learning metaverse enhances students' learning achievements in collaborative classroom settings; and second, to verify its impact on student engagement and key dimensions of PI, including responsibility, self-identity, accountability, self-efficacy, and belongingness. (1) Does the GenAI-assisted learning metaverse enhance students' learning achievement compared to a conventional type of learning metaverse for collaborative drama-based role-play? (2) To what extent do avatar construction and real-time GenAI feedback mediate participant engagement, PI, and learning achievements? By addressing these research questions, this study aims to advance the understanding of how SDT and IBM theories in technology-enhanced PBL environments can provide authentic learning opportunities for PI construction and skill development, both of which are crucial for preparing students for career readiness, while offering actionable insights for educators, researchers, system developers, and policymakers seeking to leverage the metaverse and GenAI for more effective, engaging, and future-oriented education.

2. Literature Review

2.1 Theoretical Foundation

This study integrates SDT and IBM theories to explain how metaverse learning environments, enriched with embodied interactions for problem-solving, decision-making, communication, PI, and workplace-related skills development through collaborative, drama-based role-play learning activities with GenAI feedback, can enhance career readiness in higher education. SDT emphasizes that satisfying the psychological needs for autonomy (volitional action), competence (skill mastery), and relatedness (social connection) promotes intrinsic motivation and sustained engagement (Deci & Ryan, 2000). In metaverse learning environments, these needs are addressed through avatar creation (autonomy), real-time GenAI feedback (competence), and collaborative drama-based role-play (relatedness). IBM Theory complements this by emphasizing that motivation is driven by identity congruence: learners persist when actions align with their PI and interpret challenges meaningfully (Oyserman, 2007; Oyserman & Sorensen, 2009). Metaverse environments enable students to build and express their PI by designing 3D avatars resembling themselves or aspirational roles, encouraging authentic behavior within realistic simulations (Tan et al., 2017; Zhang et al., 2022). Avatar construction enhances embodiment, agency, and identity ownership, strengthening PI (Repetto & Riva, 2023). GenAI supports this process by providing adaptive feedback aligned with learners' identity development, exemplified by AI role-play companions that guide skill-building and identity enactment in hospitality simulations (Chiu et al., 2023; Min & Cai, 2022). Together, these elements improve students' ability to apply problem-solving, communication, and responsibility skills in real-world contexts (Dahri et al., 2024).

2.2 Metaverse in Education

The metaverse, defined as a 3D digital space blending virtual and real-world elements, provides immersive, interactive platforms increasingly studied for educational potential (Park & Kim, 2022). Despite advances in platforms like Roblox, ZEPETO, and Second Life that offer seamless multisensory interactions, a significant gap remains in systematically integrating metaverse environments into higher education curricula to enhance authentic, collaborative, and career-relevant learning (Hwang & Chien, 2022; Rospigliosi, 2022; Zhang et al., 2022). Early virtual environments focused mostly on entertainment or informal learning rather than structured, curriculum-based outcomes (Davis et al., 2009; Haycock & Kemp, 2007; Livingstone & Kemp, 2006). Recent initiatives at universities such as INSEAD and the University of Pennsylvania demonstrate growing use of metaverse technologies for experiential learning, remote collaboration, and digital identity construction (Lee, 2022). However, empirical research is still limited on how these environments effectively foster PI, workplace skills, and sustained engagement in higher education. The broad technological infrastructure requirements, such as high-speed internet, cloud computing, AI analytics, and 3D modeling, present both opportunities and challenges for scalable and equitable adoption. (Gsaxner et al., 2023; Yang et al., 2022). Immersive metaverse applications have shown promise in disciplines like medicine, engineering, and business, where realistic simulations and real-time feedback benefit students (Gsaxner et al., 2023; Salloum et al., 2023; Siyaev & Jo, 2021). Yet, comprehensive empirical studies are necessary to thoroughly assess the technology's capabilities, instructional approaches, and learning outcomes. Addressing this research gap is critical for optimizing metaverse integration to enhance student engagement, professional development, and career readiness in a digitally connected world.

3. Methodology

3.1 Learning Model

Figure 1 illustrates the study's learning model, based on Morrison's Unit method of teaching and learning (Morrison, 1926), chosen for its clear structure in organizing collaborative activities. Although originally developed before immersive and AI technologies, this model was enhanced by integrating technological affordances such as real-time feedback, personalized avatar creation, and multisensory experiences. Additionally, contemporary instructional models like TPACK (Technological Pedagogical Content Knowledge) and SAMR (Substitution, Augmentation, Modification, and Redefinition), which explicitly address technology integration, could inform future research to maximize the potential of learning metaverse environments.

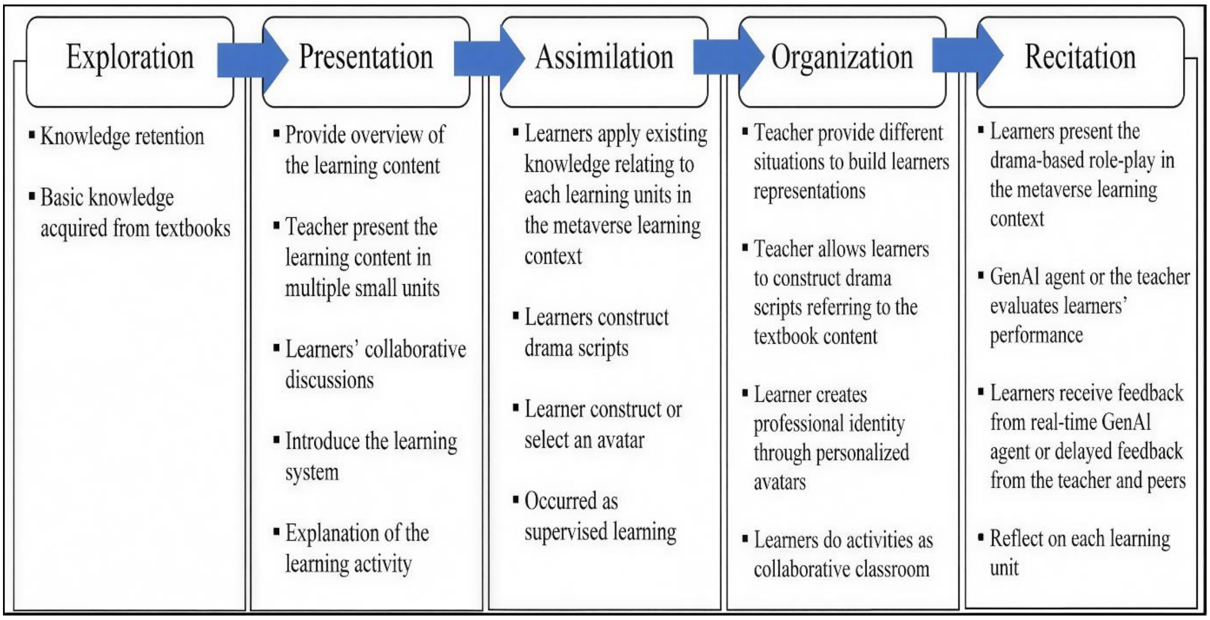

Figure 1. Learning Model

3.2 Learning Context

Figure 2 illustrates the learning context. In this context, students' avatars acted as extensions of their PI, enriching their personalized experiences inside the metaverse. Moreover, students engaged in collaborative drama-based role-play learning activities with peers while real-time GenAI agents provided guidance and feedback based on their virtual representations, facilitating meaningful learning and helping them understand and refine their mistakes immediately. Ultimately, this approach enabled students to experience personalized and immersive learning, improving their learning achievements and sustaining their motivation and engagement to learn. Figure 3 shows the classroom arrangement for the collaborative drama-based role-play learning activity in which student performers use their embodied interactions in front of the Zed2i depth camera and computer monitor, while other classmates, as the audience, observe the performance through a projection screen. The student performers have the freedom to construct their avatars and control them according to the drama script they created, and live inside the learning metaverse to complete the task.

Figure 2. Learning Context

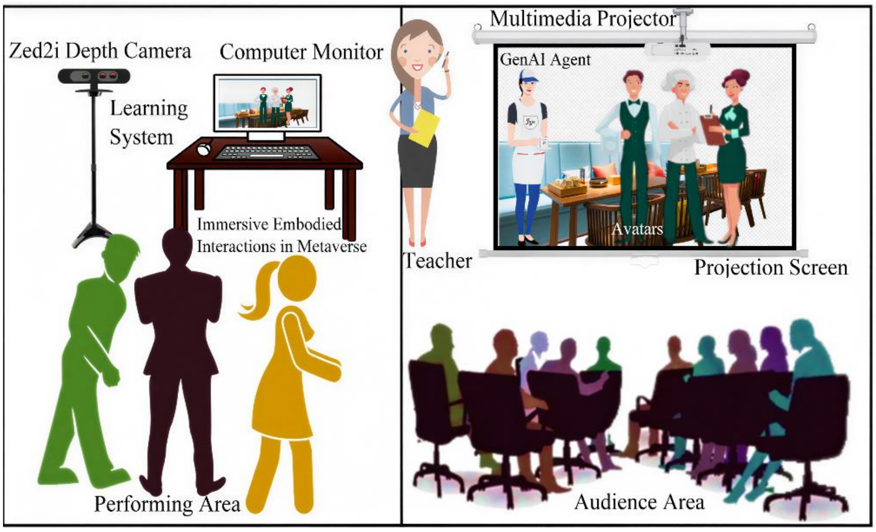

Figure 3. Classroom Arrangement for Learning Metaverse

3.3 Learning System

The learning metaverse was built on the Unity platform and uses natural user interface technologies. This learning system created an immersive, simulated environment to perform collaborative drama-based role-play learning activities in a classroom setting. This system facilitated building learner PI inside the immersive virtual simulation by allowing them to construct their personalized virtual representations as avatars. Learners designed these avatars through LLM by communicating verbally and non-verbally to the Ready Player Me platform, modifying facial features using 2D images of their faces, and also customizing gender type, skin tone, hairstyle, and clothing for highly personalized Avatar construction for better PI. The Zed2i depth camera captured learners' physical actions, behaviors, and object movements, processing them within the system to enhance immersion by synchronizing them with the learning metaverse. On the other hand, instructors could convert teaching materials into scripts, including character settings and scenes, allowing them to give feedback after the activity, oversee learning, and correct errors, thereby improving educational outcomes. Teachers could also use a rehearsal control app to evaluate learners' progress, configure scenes, and monitor learning status in real-time. By enabling the feature of GenAI agents, student performers can receive real-time feedback, oversee the learning process, and correct errors, thereby improving learners' educational outcomes. These GenAI agents provided multiple forms of feedback, such as corrective feedback (notifying students of language or role-play errors and suggesting improvements during real-time participation), reflective prompts (encouraging students to reflect on their choices and behaviors during the drama), and supportive feedback (reinforcing positive contributions, collaboration, and alignment with PI roles). Feedback was delivered in real-time via audio prompts, text overlays on avatars, and post-session summaries generated by the GenAI system, tailored to each student's avatar actions and dialogue.

3.4 Participants

This study involved 66 hospitality management majoring students (average age 18) from a university in Taiwan, working with a Japanese language instructor. The students were randomly divided into an experimental group (34 students: 11 males, 23 females) and a control group (32 students: 13 males, 19 females). Both groups completed the experiment independently to avoid any interference. Participants' identities were anonymized for confidentiality. While students had differing familiarity with GenAI tools like ChatGPT, none had used GenAI agents for learning activities before. To optimize resources, the instructor organized both groups into smaller teams of five to six students, balancing gender, communication skills, and GenAI experience.

3.5 Research Design

The study began with a knowledge retention activity on Japanese restaurant service, followed by a pre-test, unit-wise instruction, and system setup. Students engaged in the learning metaverse through drama script and avatar construction, rehearsals, and completed post-tests and questionnaires. The research examined how a GenAI-assisted learning metaverse with personalized avatars and real-time feedback for scaffolding enhances students' learning achievements and career readiness. Ethical standards, including informed consent, data anonymization, and IRB approval (NCUEREC-111-017), were maintained.

3.6 Measurements and Data Collection

A professional Japanese language instructor specializing in hospitality management designed the course materials based on the syllabus and students' proficiency, including basic vocabulary and conversational phrases relevant to the industry, which were developed into drama scripts. Pre-test and post-test, graded on a 0-100 scale and assessing cultural practices (60 points) and conversation skills (40 points), were used for both groups. ANCOVA analyzes the students' learning achievements in distinct learning approaches applied to experimental and control groups. A questionnaire, using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree), was designed to evaluate learning motivation and engagement (assessed via Intrinsic Motivation and Task Value, adapted from the Motivated Strategies for Learning Questionnaire (Pintrich et al., 1991)) and psychological ownership for better PI (measured across five dimensions based on these references (Buchem, 2012) and (Van Dyne & Pierce, 2004)) with reliability confirmed by Cronbach's alpha.

3.7 Experimental Procedure

The eight-week experiment (see Figure 4) involved both groups taught by the same instructor to ensure consistent methods. The key difference was in learning approaches: the experimental group used a GenAI-assisted learning metaverse with personalized avatars and real-time feedback, while the control group used the learning metaverse without GenAI and received delayed instructor feedback. Students were grouped using an S-curve strategy based on pre-test results. Post-tests and questionnaires assessed motivation, engagement, and psychological ownership for improved PI.

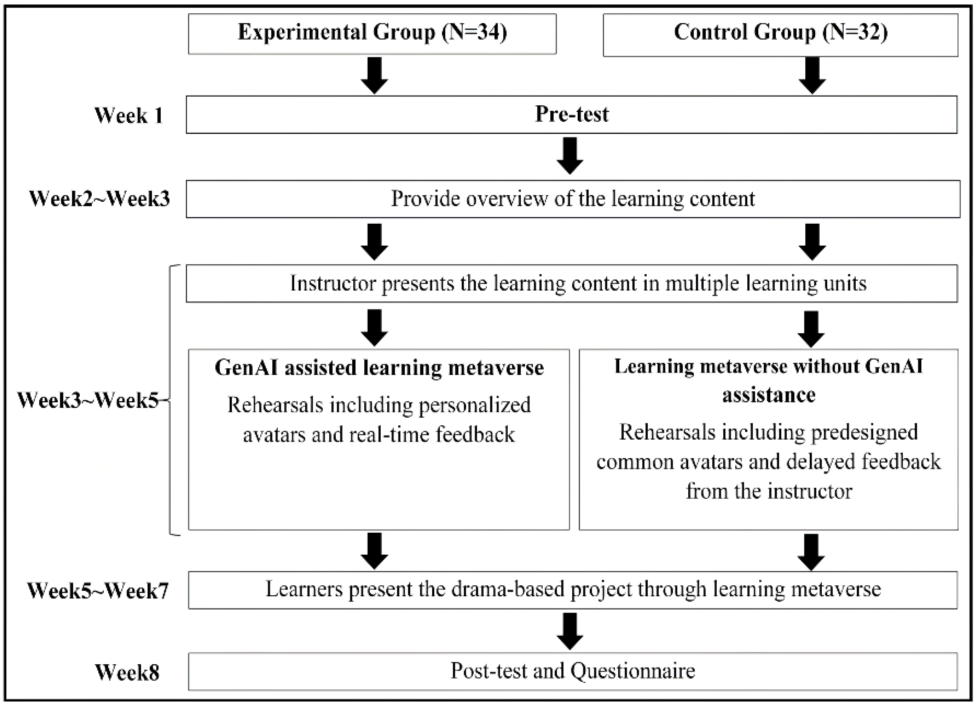

Figure 4. Experimental Procedure

4. Results

4.1 Analysis of the Students' Learning Achievement

Table *1. ANCOVA for Students' Learning Achievement*

Group	**N**	**Mean**	***SD***	**Adjusted Mean**	***SE***	***F***	**Sig.**	$\eta 2$
Experimental Group	34	84.94	8.01	84.41	1.72	4.52	0.04	0.07
Control Group	32	78.56	12.21	79.13	1.77			

This study analyzed the pre-test and post-test results of the experimental group (GenAI-assisted learning metaverse with real-time feedback) and the control group (Learning metaverse without GenAI assistance and delayed feedback) to assess students' learning achievement in the collaborative drama-based role-play learning activity. An independent samples t-test showed no significant difference in initial abilities between the groups ($p = 0.13$), confirming balanced assignment. Shapiro-Wilk analysis confirmed that both pre- and post-test scores were normally distributed ($p > 0.05$). A regression homogeneity test indicated no interaction between group and pre-test scores ($F = 0.23$, $p = 0.63$), and Levene's test validated the homogeneity of variance assumption for post-test scores ($p = 0.06$).

As shown in Table 1, a one-way analysis of covariance (ANCOVA), controlling for pre-test scores, showed significantly higher post-test scores in the experimental group compared to the control group ($F = 4.52$, $p = 0.04$). The effect size ($\eta 2$ p = 0.07) indicates a medium effect, suggesting that the GenAI-assisted learning metaverse with real-time feedback significantly improved student learning outcomes. The effect size for the ANCOVA ($\eta^2 = 0.07$) is considered medium based on Cohen's conventions: small ($\eta^2 = 0.01$), medium ($\eta^2 = 0.06$), large ($\eta^2 = 0.14$) (Cohen, 1988). Thus, the observed effect aligns with the medium benchmark for educational intervention research.

4.2 Analysis of the Questionnaire Results

This study used a highly reliable questionnaire (Cronbach's $\alpha = 0.89$) to analyze students' perceptions of the metaverse learning approaches, focusing on psychological ownership and engagement. In terms of psychological ownership, the experimental group significantly outperformed the control group ($p < 0.05$) across the sub-dimensions of responsibility, self-identity, self-efficacy, and belongingness.

Regarding responsibility, the experimental group averaged 4.38 compared to 3.91 for the control group ($p = 0.00$), indicating a stronger sense of responsibility among experimental students. For self-identity, the experimental group averaged 4.35 versus 3.97 for the control group ($p = 0.03$), showing a stronger connection to their learning outcomes. In self-efficacy, the experimental group averaged 4.29, while the control group scored 3.75 ($p = 0.01$), suggesting greater confidence in completing tasks. Finally, for belongingness, the experimental group averaged 4.38 compared to the control group's 4.00 ($p = 0.03$), indicating a greater sense of belonging in collaborative learning tasks (teamwork).

While the accountability dimension didn't show a significant difference ($p > 0.05$). Therefore, it cannot be concluded that the treatment increased accountability; any mean difference may be attributable to random variation or measurement error rather than the intervention itself. Accordingly, the experimental group scored higher (4.21 versus 3.94), suggesting a stronger sense of accountability. Overall, the findings suggest that the GenAI-assisted learning metaverse with a real-time feedback approach significantly enhances various aspects of students' psychological ownership and engagement with higher PI and may positively influence learning motivation.

Table 2. *Questionnaire Results Analysis*

Facets	Group	Mean	*SD*	Sig.
Sense of Responsibility	Experimental Group	4.38	0.65	0.00
	Control Group	3.91	0.78	
Sense of Self-identity	Experimental Group	4.35	0.65	0.03
	Control Group	3.97	0.78	
Sense of Accountability	Experimental Group	4.21	0.85	0.20
	Control Group	3.94	0.84	
Sense of Self-efficacy	Experimental Group	4.29	0.72	0.01
	Control Group	3.75	0.80	
Sense of Belongingness	Experimental Group	4.38	0.60	0.03
	Control Group	4.00	0.76	

5. Discussion and Conclusions

This study investigated the potential of collaborative drama-based role-play learning activities within an authentic classroom context by employing a GenAI-assisted learning metaverse with real-time feedback to enhance students' learning achievement. This approach enabled learners to engage interactively through personalized digital avatars and develop their understanding within digital realities while strengthening their PI. Students utilized tools such as Ready Player Me and Blender to design their avatars, Mixamo for real-time motion capture with a Zed2i depth camera, and integrated physical and virtual elements using the YOLO algorithm combined with OpenCV libraries and Polycam technologies. These technologies collectively fostered active learning by promoting creativity, increasing engagement, and enhancing intrinsic motivation and psychological ownership through student control over the design and construction processes. Such findings are consistent with prior research demonstrating that avatar customization and embodied interactions in metaverse environments support autonomy and identity development, which are critical for motivation and engagement (Hwang & Chien, 2022; Oyserman, 2007; Park & Kim, 2022).

Statistical analyses revealed that the experimental group exhibited significantly higher intrinsic motivation and task value compared to the control group. Improvements were also observed in key psychological ownership dimensions, including responsibility, self-identity, self-efficacy, and belongingness. These outcomes align with SDT, which emphasizes the importance of satisfying autonomy, competence, and relatedness needs to foster motivation and engagement (Chiu et al., 2023; Ryan & Deci, 2002). However, no significant difference was found in accountability between the groups, suggesting that accountability may be influenced more by external expectations and institutional norms than by internal motivational factors or identity congruence. This finding echoes previous studies indicating that accountability often requires clearly defined external standards and social reinforcement beyond the scope of autonomous learning environments (Tan et al., 2017).

The project-based, collaborative learning environment focused on constructing virtual scenarios and physical prototypes reflects the integration of SDT and IBM theories. LLMs played a critical role in scaffolding task design and construction, enabling students to generate creative drama scripts, 3D environments, and prototype sketches. This facilitated self-regulated learning and iterative refinement, demonstrating how accessible technologies can lower barriers to complex 3D modeling and scenario creation, thereby supporting broader adoption in educational settings. These results support previous findings that AI-powered tools can enhance personalized learning experiences and promote deeper cognitive engagement (Salloum et al., 2023). While technological challenges persist, targeted teacher training and the development of user-friendly resources are effective strategies to overcome these obstacles and support educators in implementing metaverse-based learning (Kshetri et al., 2022; Siyaev & Jo, 2021).

In conclusion, the findings of this study provide strong evidence that combining learning metaverse platforms with GenAI assistance significantly enhances students' psychological ownership, engagement, and learning outcomes. This supports the growing body of literature advocating for immersive, student-centered learning environments that integrate advanced technologies with robust pedagogical frameworks (Park & Kim, 2022; Ryan & Deci, 2020). Future research should focus on strategies to strengthen students' sense of accountability within these environments, investigate the long-term effects of immersive, metaverse experiences on learning and PI development, and refine teacher support models to facilitate scalable implementation in formal education. By advancing the integration of LLMs, metaverse technologies, and motivational theories, educators and researchers can continue to innovate technology-supported learning and foster authentic, engaging, and career-relevant educational experiences.

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