Development of An Online Metaverse Lesson Using Self-Directed Learning to Enhance Problem-Solving Ability

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Abstract

This study aimed to: (1) develop an online Metaverse lesson using self-directed learning to enhance problem-solving ability, (2) compare pre-test and post-test learning achievement, (3) compare problem-solving ability before and after learning, and (4) assess students' satisfaction. The target group comprised 49 undergraduate students from Chanthaburi College of Dramatic Arts enrolled in the course 300-11003 Life Skills in Higher Education in the Digital Age during the first semester of the 2024 academic year. A one-group pretest-posttest experimental design was employed. Research instruments included: (1) structured interviews, (2) lesson plans, (3) an online Metaverse lesson using self-directed learning, (4) a learning achievement test, (5) a problem-solving ability assessment, and (6) a student satisfaction questionnaire. The findings revealed that: (1) the quality of the online Metaverse lesson was rated as excellent by experts ($\bar{X}$= 4.52, SD = 0.55), (2) students' problem-solving ability significantly improved after learning ($\bar{X}$= 21.22, SD = 1.92) compared to before learning ($\bar{X}$= 13.51, SD = 2.39), (3) students' post-learning achievement ($\bar{X}$= 33.47, SD = 3.37) was significantly higher than pre-learning achievement ($\bar{X}$= 17.27, SD = 3.21), and (4) students reported a high level of satisfaction with the learning module ($\bar{X}$= 4.59, SD = 0.48). These findings suggest that an online Metaverse lesson using self-directed learning is an effective approach to enhancing both learning achievement and problem-solving skills. Additionally, it promotes positive learning experiences, fostering deeper learning engagement. This research provides a foundation for the future development of technology-driven instructional media to improve education for diverse learners.

Keywords: Online Metaverse Lesson, Self-Directed Learning, Problem-Solving Ability

Introduction

Emerging technological innovation that is being integrated into educational settings for next-generation learners. The Metaverse helps overcome real-world learning limitations, enhances teaching methodologies, and provides immersive learning experiences that may not be possible in traditional classrooms. The term Metaverse refers to a virtual world where users with shared interests come together in an online social environment, fostering global interaction beyond physical boundaries (Institute for the Promotion of Teaching Science and Technology, 2022).

The COVID-19 pandemic in 2020 forced educational institutions to shift toward online learning. The crisis led to the enforcement of strict measures to contain the virus, which significantly impacted the delivery of education. As a result, multiple teaching methods were adopted to align with emerging educational demands. During this period, Metaverse technology facilitated communication and interaction between teachers and students, enabling students to conduct self-directed learning anytime and anywhere (Jaitip Na Songkhla, 2022). Virtual classrooms within the Metaverse create interactive online environments, where students and teachers engage in realistic simulations, increasing student confidence in asking and answering questions. Adapting Metaverse technology in education enhances student engagement and expands self-directed learning potential through diverse multimedia content (Yupawadee Promsathian & Theerachai Netthanomsak, 2021). The successful integration of virtual classrooms into traditional education requires effective learning strategies, such as active learning, inquiry-based learning, and self-directed learning.

Knowles (1975) defined self-directed learning (SDL) as a process in which learners take responsibility for their own learning, without relying solely on instructors. SDL allows students to expand their knowledge, develop skills, and gain experiences through independent exploration of learning resources and experts. Unlike teacher-directed learning, which focuses on external motivation and structured content, self-directed learning promotes intrinsic motivation, encouraging students to take ownership of their learning process. Knowles (1970) emphasized that SDL requires learners to assess their own educational needs, guiding them toward personalized learning goals.

Brockett and Hiemstra (2018) described self-directed learning as a combination of: (1) an instructional method process and (2) individual personality traits related to learning autonomy. They introduced the Personal Responsibility Orientation (PRO) model, which highlights the importance of personal responsibility in directing one's own learning. This model serves as a framework for higher education and adult learners, supporting autonomous and lifelong learning practices.

Developing problem-solving skills is a key objective in higher education, as it enables students to apply knowledge in real-world scenarios. Problem-posing and inquiry-based learning have been recognized as essential elements of effective teaching methodologies (Ilana & Atara, 2007). Encouraging students to formulate problems fosters curiosity, imagination, and critical thinking, which are integral components of 21st-century skills (Wicharn Panich, 2012). Problem-solving involves three core processes: (1) problem identification, (2) solution generation, and (3) selecting the most appropriate method (Isaksen & Treffinger, 2004; Wichuda Malasai, 2018). These skills are essential for students to adapt to real-world challenges and make informed decisions.

Given these factors, this study aimed to develop an online Metaverse lesson integrated with self-directed learning to enhance undergraduate students' problem-solving abilities. The findings contribute to innovative instructional design that improves problem-solving competencies while supporting self-directed learning through advanced technologies. The study aligns with 21st-century educational needs, fostering sustainable learning environments that prepare students for real-world applications.

Research Objectives

1. To develop an online Metaverse lesson using self-directed learning to enhance problem-solving ability in undergraduate students.
2. To compare students' problem-solving abilities before and after using the learning module.
3. To compare pre-test and post-test learning achievement using the developed learning module.
4. To examine students' satisfaction with the Metaverse-based learning experience.

Literature Review

The integration of emerging technologies into education has transformed traditional pedagogical approaches, enabling novel forms of learning and interaction. Among these innovations, the Metaverse—a collective virtual shared space—has garnered significant attention in educational research due to its potential to create immersive, engaging, and interactive learning environments that transcend physical constraints. This literature review synthesizes key theoretical perspectives and empirical studies relevant to three core concepts of the present study: the Metaverse in education, self-directed learning (SDL), and the development of problem-solving ability in the context of higher education.

1. The Metaverse as an Educational Platform. The Metaverse, defined as a persistent, 3D virtual environment where users interact via avatars, offers vast potential for educational transformation. It allows for real-time engagement, collaborative learning, and immersive simulations that mirror real-world scenarios (Institute for the Promotion of Teaching Science and Technology, 2022). According to Yupawadee Promsathian and Theerachai Netthanomsak (2021), the Metaverse supports active participation and fosters learner motivation by integrating various multimedia components, such as audio-visual materials, animations, and virtual discussion forums.

The COVID-19 pandemic accelerated the adoption of digital learning environments, with the Metaverse emerging as a promising alternative to conventional classrooms. Jaitip Na Songkhla (2022) emphasized that Metaverse classrooms enhance student autonomy and interaction through self-paced, virtual simulations, thus making education accessible beyond time and place constraints. Moreover, Thanaphat Sripan (2022) described the Metaverse as a “three-dimensional networked learning space” where learners collaborate, communicate, and explore, making it a suitable medium for constructivist and inquiry-based pedagogy.

2. Self-Directed Learning (SDL) Theory. Self-directed learning is a foundational theory in adult education, defined by Knowles (1975) as a process in which individuals take initiative—independently or with guidance—in diagnosing their learning needs, formulating goals, identifying resources, and evaluating outcomes. Knowles (1970) contrasted SDL with traditional pedagogical approaches, emphasizing learner autonomy, intrinsic motivation, and personalized educational experiences.

Expanding on Knowles’ work, Brockett and Hiemstra (2018) proposed the Personal Responsibility Orientation (PRO) Model, which integrates instructional strategies with learner traits, highlighting the importance of individual accountability and motivation in directing one’s learning. SDL is particularly relevant in online and technology-mediated contexts, where students must actively manage their learning paths. Vichit Yodwijakchayothin (2021) affirmed that incorporating SDL in digital platforms empowers learners to develop critical skills through goal-setting, resource selection, and reflective assessment.

3. Problem-Solving Ability in Higher Education. Problem-solving is a core component of 21st-century skills, encompassing the capacity to identify issues, generate and evaluate solutions, and implement effective strategies. Ilana and Atara (2007) emphasized the importance of problem-posing as a cognitive strategy that nurtures curiosity and creativity. Wicharn Panich (2012) argued that educational systems must shift from rote learning to experiential models that challenge students to engage in real-world problem analysis and decision-making.

Isaksen and Treffinger (2004) classified the problem-solving process into three key stages: (1) identifying and understanding the problem, (2) generating potential solutions, and (3) selecting and applying the most appropriate solution. These cognitive stages align with self-directed learning processes, suggesting that SDL environments, such as those enabled by the Metaverse, are well-suited for cultivating problem-solving competence.

Empirical studies support this integration. For instance, Hamdi Bunae (2023) found that high school students’ problem-solving abilities significantly improved after engaging with Metaverse-based learning that emphasized creative exploration. Likewise, Vichuda Malasai (2018) demonstrated the effectiveness of instructional models designed to promote problem-solving through active learning strategies.

4. Intersection of Metaverse, SDL, and Problem-Solving. The intersection of Metaverse technology, SDL, and problem-solving ability presents a promising instructional paradigm. Research suggests that Metaverse platforms provide the contextual immersion necessary for SDL, while also presenting authentic problems that require strategic thinking and collaboration. Surapol Bunlue (2022) argued that immersive virtual environments support deep learning by connecting digital simulations with real-life challenges, thus reinforcing the application of theoretical knowledge.

Additionally, studies by Wanvisa Inpan (2014) and Lilla Adulyasan (2018) revealed that virtual classrooms incorporating SDL principles lead to higher learner engagement and satisfaction. These findings underscore the synergy between learner autonomy and interactive technology in fostering academic achievement and skill development.

In summary, the literature affirms that integrating Metaverse technology with self-directed learning strategies effectively supports the development of students' problem-solving abilities. Theoretical contributions from Knowles (1970, 1975) and Brockett & Hiemstra (2018) guide the instructional design toward learner autonomy, while cognitive models of problem-solving from Isaksen & Treffinger (2004) and Panich (2012) inform task structuring within the virtual environment. Prior empirical research supports the effectiveness of Metaverse-enabled, SDL-based learning in enhancing student engagement, learning achievement, and cognitive skills.

However, despite the growing body of literature, few studies have systematically designed and assessed Metaverse-based lessons that incorporate SDL principles specifically to enhance problem-solving skills among undergraduate students in Thai higher education. This research aims to address that gap by developing and evaluating an online Metaverse lesson designed to foster self-directed learning and improve students' problem-solving abilities, thereby contributing to innovative pedagogical practices aligned with 21st-century learning goals.

Methodology

This study employed a one-group pretest-posttest experimental design to evaluate the effectiveness of an online Metaverse lesson using self-directed learning on students' problem-solving abilities. The research process was divided into three phases:

Phase 1: Development of the Online Metaverse Lesson Combined with Self-Directed Learning to Enhance Problem-Solving Ability

The development phase involved synthesizing instructional components of self-directed learning and designing an online Metaverse lesson tailored to enhance students' problem-solving skills. This phase covered lesson planning, online media integration, lesson content development, information structuring, and visual presentation aligned with Metaverse-based self-directed learning principles.

1.1 Participants : Experts were selected through purposive sampling (Kamberelis & Dimitriadis, 2005; Krueger, 2014). Three experts in educational technology (Metaverse-based online learning) and three experts in instructional design (self-directed learning and problem-solving pedagogy) were invited, all with a minimum of five years of relevant experience.

1.2 Research Instruments

Structured Interview. Section 1: General information, including gender, education level, field of study, expertise, and organizational affiliation. Section 2: Content-related inquiries on Metaverse-based online learning integrated with self-directed learning to enhance problem-solving abilities. The structured interview was validated for content accuracy using the Item-Objective Congruence (IOC) index, which yielded a perfect score of 1.00, indicating excellent agreement among the experts.

1.3 Data Collection

The researcher formally invited six experts to participate in interviews. Individual interviews were conducted based on scheduled appointments, allowing experts to freely express their insights and provide constructive recommendations.

1.4 Data Analysis

Data collected from expert interviews were synthesized and analyzed using content analysis. The insights and suggestions were incorporated into the refinement of the online Metaverse lesson, ensuring alignment with self-directed learning and problem-solving development principles. The revised lesson was then prepared for Phase 2 implementation.

Phase 2: Implementation and Evaluation of the Online Metaverse Lesson

The second phase involved implementing the developed Metaverse-based lesson with first-year undergraduate students at Chanthaburi College of Dramatic Arts. The objective was to evaluate learning achievement and problem-solving ability before and after using the lesson.

2.1 Participants and Sample Selection

The population comprised 176 undergraduate students enrolled in the Bachelor of Education program at Chanthaburi College of Dramatic Arts in the second semester of the 2024 academic year.

The sample group included 49 students registered in the course 300-11003 Life Skills in Higher Education in the Digital Age, selected through simple random sampling.

2.2 Research Instruments

(1) Learning Achievement Test assessing knowledge across three units. Unit 1: Study techniques in higher education. Unit 2: Learning processes and academic resources. Unit 3: Library usage and internet research. The test comprised 40 multiple-choice questions, with a total score of 40. The researcher submitted the achievement test to three experts to evaluate its quality using the Item-Objective Congruence (IOC) technique to ensure alignment between each item and the content. Test items with an IOC value of 0.50 or higher were selected, following the guideline of Pannee Leekitwattana (2012). After expert review, the test was revised and refined for accuracy and clarity. Subsequently, the improved test was administered in a try-out phase with 30 students who were not part of the actual sample group. The collected data were then analyzed to assess the test's quality by calculating: (1) Item difficulty index (p), (2) Item discrimination index (r), and (3) Test reliability, determined using the Kuder-Richardson Formula 20 (KR-20).

(2) Problem-Solving Ability Assessment, adapted from Plokrit Tantiyanukul (2004), covering: Identifying the problem, Analyzing the problem, proposing solutions, Selecting the best solution. The assessment tool was submitted to experts for validation. The Item-Objective Congruence (IOC) index was calculated to ensure content validity, and the resulting IOC score

was 1.00, indicating perfect agreement among the experts on the relevance and appropriateness of the assessment items.

(3) Lesson Plan integrating the Metaverse-based online learning environment with self-directed learning strategies. The Item-Objective Congruence (IOC) index was calculated, yielding a perfect score of 1.00, indicating complete agreement among the experts regarding the appropriateness and relevance of the lesson components.

(4) Self-Directed Learning Process in the Online Metaverse Lesson The instructional design followed a five-step self-directed learning framework within the Metaverse environment:

1) Readiness Triggers – Students were encouraged to recognize their learning needs by engaging in preparatory activities, such as problem-based discussions, self-reflection exercises, and goal-setting tasks.

2) Setting Goals – Learners established clear, individualized learning objectives that aligned with course expectations and personal growth goals.

3) Planning – Students devised study schedules, selected learning methods, and determined resource utilization strategies that fit their preferred learning styles.

4) Learning Activities – Engaged in interactive Metaverse simulations, collaborative discussions, and knowledge exploration through virtual learning tools.

5) Evaluation – Learning progress was assessed through self-reflection, instructor feedback, peer evaluations, and structured tests to measure knowledge acquisition and problem-solving improvement.

(5) Student Satisfaction Survey, designed to assess learners' perceptions of the Metaverse-based self-directed learning experience. The questionnaire was reviewed by a panel of experts to evaluate content validity. The Item-Objective Congruence (IOC) index was calculated, resulting in a perfect score of 1.00, indicating unanimous agreement among experts on the relevance and clarity of the survey items.

2.3 Data Collection and Analysis

This study employed a one-group pretest-posttest experimental design (Mariam Nilpan, 2004). The sample group participated in pretest assessments, engaged in the online Metaverse lesson integrated with self-directed learning, and then completed posttest assessments to measure learning outcomes and problem-solving abilities.

The research process followed these structured steps:

2.3.1 Analysis and Planning The researcher reviewed relevant theories, concepts, and previous research to synthesize key principles for instructional design. Learner analysis and curriculum assessment were conducted, incorporating expert feedback from Phase 1 interviews into the instructional design plan.

2.3.2 Instructional Design The instructional framework was developed based on expert input. Behavioral learning objectives, assessment criteria, and instructional strategies were outlined. The lesson structure incorporated self-directed learning strategies and problem-solving tasks.

2.3.3 Development of Research Instruments The following instruments were designed and refined: 1) Structured Interview Guide for expert consultations. 2) Lesson Plan for the Metaverse-based self-directed learning module. 3) Online Metaverse Lesson developed based on expert feedback. 4) Problem-Solving Ability Assessment, measuring problem identification, analysis, solution generation, and selection. 5) Learning Achievement Test, aligned with course objectives. 6) Student Satisfaction Questionnaire, using a 5-point Likert scale.

2.3.4 Implementation of the Experiment 1) Preparation Phase Coordination with academic administrators to facilitate the experiment. Scheduling and logistical arrangements for the experiment. Distribution of formal requests to relevant departments. Selection of 49 first-year students for participation. 2) Execution Phase (Three Weeks) Week 1: Readiness Triggers and Goal Setting. Week 2: Planning and Learning Activities. Week 3: Evaluation and Reflection. 3) Post-Experiment Phase Students completed problem-solving assessments and learning achievement tests. Satisfaction surveys were administered.

2.4 Data Analysis

Statistical methods included mean, standard deviation, t-test (dependent samples), item-objective congruence (IOC), difficulty index (P), discrimination index (R), and reliability analysis.

Phase 3: Validation of the Online Metaverse Lesson

The validation phase was conducted to ensure that the developed online Metaverse lesson using self-directed learning is appropriate for undergraduate education and effective in enhancing problem-solving ability. This validation involved expert evaluation following these steps:

3..1 Participants : Experts were selected through purposive sampling (Kamberelis & Dimitriadis, 2005; Krueger, 2014). The expert panel consisted of: Three specialists in educational technology (Metaverse-based online learning). Three specialists in instructional methodology (self-directed learning and problem-solving instruction). Each expert had at least five years of relevant experience in their respective fields.

3.2 Research Instrument : Validation Questionnaire: A structured assessment form was used to evaluate the appropriateness, usability, and effectiveness of the Metaverse lesson.

3.3 Data Collection : Official invitations were sent to experts for validation assessment. Experts were provided with the Metaverse lesson materials 14 days in advance to review the content, instructional design, and overall effectiveness. After completing the validation questionnaire, experts provided qualitative feedback and suggestions for improvement.

3.4 Data Analysis : The mean and standard deviation of expert ratings were calculated. Qualitative feedback was analyzed through content analysis. The Likert 5-point scale was used for expert evaluation.

Results

1. Develop an online Metaverse lesson using self-directed learning.

The development of the online Metaverse lesson combined with self-directed learning was implemented in the Life Skills in Higher Education in the Digital Age course. The learning module was published on the website https://www.spatial.io/s/ONLINE-METAVERSE-LESSON-by-Dr-Riana-67a1d5157d84d1b49e3fd16a?share=2779140560260041840. The instructional design involved selecting multimedia tools to create an engaging online lesson. Various elements such as text, animations, images, sound, assignment boards, and discussion forums were incorporated into the lesson structure. The interface design was carefully crafted with aesthetic graphics and user-friendly navigation to enhance learners' engagement and interaction.

1.1 Quality of the Online Metaverse Lesson

The overall expert evaluation rated the lesson as excellent ($\bar{X}$= 4.52, SD = 0.55). This rating reflects the module's well-designed interactive features, the highest score is Lesson Design ($\bar{X}$= 4.55, SD = 0.57), Interface and Visual Design ($\bar{X}$= 4.53, SD = 0.51), Accessibility and Usability ($\bar{X}$= 4.52, SD = 0.52) and Content Quality ($\bar{X}$= 4.44, SD = 0.58)

Table 1 Quality of the Online Metaverse Lesson

Item	Result		Definition
	$\bar{X}$	S.D.	
1. Content Quality	4.44	0.58	Good
2. Lesson Design	4.55	0.57	excellent
3. Interface and Visual Design	4.53	0.51	excellent
4. Accessibility and Usability	4.52	0.52	excellent
Total	**4.52**	**0.55**	**excellent**

2. Problem-Solving Ability Improvement

Students' post-test scores ($\bar{X}$= 21.22, SD = 1.92) were significantly higher than pre-test scores ($\bar{X}$= 13.51, SD = 2.39) (t = 5.41, $p < 0.05$). This indicates a substantial improvement in students' analytical and decision-making skills after engaging with the Metaverse-based learning module.

Table 2 Compare students' problem-solving abilities

Score	Full score	$\bar{X}$	S.D.	t-test
Pretest	25	13.51	2.39	5.41
Posttest	25	21.22	1.92	
*Statistically significant at the .05 level.				

3. Learning Achievement

Post-test scores ($\bar{X}$= 33.47, SD = 3.37) were significantly higher than pre-test scores ($\bar{X}$= 17.27, SD = 3.21) (t = 5.90, $p < 0.05$). The significant increase suggests that the Metaverse learning environment effectively enhances students' understanding and retention of course content.

Table 3 compare pre-test and post-test learning achievement

Score	Full score	$\bar{X}$	S.D.	t-test
Pretest	40	17.27	3.21	5.90
Posttest	40	33.47	3.37	
*Statistically significant at the .05 level.				

4. Student Satisfaction

Participants expressed high satisfaction with the learning module ($\bar{X}$= 4.59, SD = 0.48). The highest-rated aspects were the use of immersive technology ($\bar{X}$= 4.70, SD = 0.45) and interactive learning activities ($\bar{X}$= 4.61, SD = 0.49), which facilitated an engaging and effective learning experience.

Item	$\bar{X}$	S.D.	Definition
1. Format/Characteristics of teaching media	4.50	0.49	excellent
2. Content	4.56	0.50	excellent
3. interactive learning activities	4.61	0.49	excellent
4. the use of immersive technology	4.70	0.45	excellent
Total	**4.59**	**0.48**	**excellent**

Discussion and Conclusion

1. Development of the Online Metaverse Lesson Combined with Self-Directed Learning

The online Metaverse lesson was designed systematically following the ADDIE Model, ensuring that the content was well-structured and met learners' needs. The curriculum was analyzed to align content with learning objectives, and the instructional plan was carefully reviewed for accuracy, coherence, and language appropriateness. The learning module was also tested and evaluated for effectiveness. This is consistent with the research of Yod Wijakchayothin (2021), who studied the development of a competency-enhancing model for

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teachers in online learning management at Bangkok Christian College using the ADDIE Model. His study found that the model demonstrated high effectiveness in instructional design.

2. Comparison of Pre-Test and Post-Test Problem-Solving Scores

The comparison of students' problem-solving ability before and after using the Metaverse lesson revealed a statistically significant difference at the 0.05 level, with post-test scores being higher. This result supports the study’s hypothesis, indicating that the structured learning environment within the Metaverse facilitated easier access to problem-solving scenarios through immersive virtual interactions. The incorporation of self-directed learning methods encouraged students to actively engage in critical thinking, question-driven learning, and independent problem exploration. These findings align with Hamdi Bunae (2023), whose research demonstrated that high school students’ problem-solving skills significantly improved after engaging in a Metaverse-based virtual classroom using a creative-based learning approach. His study found that the post-test problem-solving scores exceeded the 70% proficiency benchmark, showing statistical significance at $p < 0.05$.

3. Comparison of Pre-Test and Post-Test Learning Achievement

The study found that students' post-test learning achievement scores were significantly higher than their pre-test scores, confirming the study’s hypothesis. This improvement can be attributed to the flexibility of Metaverse-based learning, which allows students to access lesson content anytime and anywhere. Additionally, learning through multimedia-enhanced online platforms enables students to review course materials independently and explore external learning resources. These findings are consistent with Surapol Bunlue (2022), who studied the role of Metaverse in education, emphasizing how virtual learning environments connect the digital and real-world learning experience. His research found that immersive experiences through avatars enhance engagement and learning effectiveness. Similarly, Thanaphat Sripan (2022) described the Metaverse as a three-dimensional virtual network that enables interaction, discussion, and collaboration in education, supporting self-directed learning. The research by Saksayam Suthat (2021) further supports this, showing that vocational students who engaged in self-directed learning achieved significantly higher post-test learning scores, with statistical significance at $p < 0.05$

4. Student Satisfaction with the Online Metaverse Lesson

The results revealed that students had the highest level of satisfaction with the Metaverse-based learning experience. When analyzed by category, the highest-rated aspects were: (1) benefits gained from learning, (2) learning activities, (3) lesson content, and (4) the format of instructional media. Students reported that Metaverse-based instruction was more engaging and enjoyable than traditional learning, as it incorporated technology-driven interactions and immersive experiences. These findings align with Lilla Adulyasan (2018), who found that integrating technology into teaching positively influenced students’ attitudes, creating engaging and effective learning experiences. Additionally, Wanvisa Inpan (2014) studied virtual classrooms with collaborative learning and found that students exhibited high satisfaction with immersive digital learning environments.

New Knowledge Generated from the Research

The research contributes new knowledge by synthesizing a Metaverse-Based Self-Directed Learning Framework to enhance problem-solving abilities among undergraduate students. The framework integrates instructional design, technological immersion, and self-regulation strategies, forming a holistic approach to 21st-century learning. This knowledge addresses the educational gap in implementing virtual learning environments that foster learner autonomy and cognitive skill development.

Recommendations

Suggestions for Implementation

1. Institutions should develop Metaverse-based learning environments in different disciplines to enhance students' engagement and independent learning.

2. Educators should be trained in designing and implementing Metaverse lessons that integrate self-directed learning principles effectively.

3. Digital infrastructure should be improved to support seamless connectivity and immersive experiences, reducing technical barriers for students.

Recommendations for Future Research

1. Comparative studies should be conducted to analyze the effectiveness of Metaverse-based learning compared to traditional and hybrid learning models.

2. Future research should explore the impact of Metaverse learning on different cognitive skills, including creativity, collaboration, and problem-solving.

3. Studies should investigate ethical considerations and data privacy concerns associated with Metaverse-based education to ensure student security and inclusivity.

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