Metaverse Learning Experience Platform (MLXP) for Immersive Design Thinking to Enhance Digital Intelligence Quotient and Virtual Game Developer Skills

N. Wannapiroon, S. Shawarangkoon, C. Chawarangkoon*, A. Kucharoenthavorn, and P. Wannapiroon

***Abstract*—A Metaverse Learning Experience Platform (MLXP) is needed to enhance undergraduate students' creative innovation and professional advancement in multimedia technology and gaming business. This learning aid utilizes immersive design thinking methodology, transforming classroom teaching, connecting teachers and students, and enhancing learning outcomes. This study aims to develop a MLXP for immersive design thinking to enhance the digital intelligence quotient and virtual game developer skills. The research methodology involved three phases: developing the MLXP, developing the immersive design thinking process, and evaluating the skills. The sample group consisted of 36 undergraduate students from the Faculty of Science and Technology at Rajamangala University of Technology Suvarnabhumi, who were enrolled in a game design and game development course from academic year 2022. The research instruments consisted of MLXP, immersive design thinking lesson plan, Digital Intelligence Quotient (DQ) and virtual game developer skills assessment form. The MLXP consisted of 14 components, including a Metaverse Learning management system, metaverse content management system, metaverse content delivery system, metaverse personalized learning tools, analytics and reporting tools, assessment and evaluation tools, immersive collaboration tools, immersive virtual learning space, online self-paced learning space, immersive virtual meeting space, immersive virtual co-working space, immersive virtual presentation space, immersive virtual exhibition space, and immersive virtual portfolio space. The immersive design thinking process on the MLXP involved six steps: empathize, define, ideate, prototype, test, and share. The MLXP and learning process were found to be appropriate at an excellent level, and undergraduate students studying using the MLXP demonstrated excellent digital intelligence quotient and game developer skills.**

***Index Terms*—Metaverse, learning platform, design thinking, digital intelligence quotient, virtual game developer**

I. Introduction

The use of metaverse technology will be one of the future trends in educational innovation. Utilizing virtual and augmented reality to create immersive learning experiences will be one of the trends. This enables students to engage with virtual worlds and simulations in ways that can improve comprehension. Another trend is the use of metaverse technology to support online and remote learning, giving students access to learning materials and establishing connections with peers and teachers from any location. This is crucial in light of the significant school and university closures brought on by the COVID-19 pandemic. Additionally, there was an increase in the use of metaverse technology to create virtual campuses, where students can interact with each other and attend virtual classes, lectures, and other events [1, 2].

During the epidemic, hybrid classrooms have grown more and more typical. Digital technology have sped up the move to the modern university. One of the Industry 4.0 emerging technologies, Digital Twins technology, aids instructors in developing simulation models in accordance with course requirements. Universities continue to struggle with how to provide excellent learning opportunities without endangering the participants' health. To that purpose, the current study provides a Hybrid Model that has been successfully deployed and verified inside the Teaching Factory framework idea. In four hybrid case studies, engineering students completed training webinars in the areas of maintenance and Computer-Aided Manufacturing (CAM) while guiding laboratory staff remotely towards the successful fabrication and assembly of bespoke project assignments [3].

Design thinking is a problem-solving approach that emphasizes empathy, experimentation, and iteration. Design thinkers can prototype and test ideas in virtual worlds using immersive, interactive surroundings made possible by metaverse technology. This can be accomplished by building virtual versions of the goods, services, or places and then testing them with people in a computerized environment. To enable designers to test various concepts, ideas, and solutions in a virtual environment, virtual prototyping environments are one way to use the metaverse for design thinking. This can be done by creating virtual models of products, services, or environments, and then testing them with users in a virtual setting. One way to use the metaverse for design thinking is to create virtual prototyping environments that enable designers to test different ideas, concepts, and solutions in a virtual setting. This can be done by creating a virtual world that simulates the real-world conditions in which a product or service will be used. When compared to a physical prototype, virtual prototyping allows designers to test and refine their ideas in a virtual setting, which can save time and money. Making virtual workspaces for designers to collaborate in order to co-create and co-design solutions is another technique to use the metaverse for design thinking. This can

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be accomplished by developing a virtual environment that enables designers to connect, communicate, and work together virtually. Virtual collaboration spaces may improve teamwork and communication, which in turn can boost innovation and creativity [4, 5].

Digital Intelligence Quotient (DQ) refers to an individual's ability to understand and use technology effectively. It encompasses a range of skills including digital literacy, digital communication, digital creativity, digital collaboration, and digital problem-solving. Higher education students with high DQ are better equipped to navigate the digital world and succeed in a rapidly-changing technological landscape. Having high DQ is important for higher education students because it enables them to be more effective learners and better prepared for the workplace. Digital literacy, for instance, it's essential to give students the ability to acquire, analyze, and use data from digital sources. Students that are proficient in digital communication can collaborate and communicate efficiently in online settings. Students may 'think beyond the box' and develop creative solutions thanks to digital inventiveness. Students who are proficient in digital cooperation can function well in virtual teams. Last but not least, digital problem-solving enables students to troubleshoot and resolve technical issues [6, 7].

Virtual game development is an emerging field that involves the design, creation and production of virtual reality and augmented reality games and simulations. Virtual game development skills are becoming increasingly important for higher education students, as they provide them with the knowledge and abilities needed to create, design and develop immersive experiences in a virtual environment. Skills for creating virtual games can be used in a variety of contexts, such as education, training, entertainment, and marketing. Virtual games and simulations can be used in education to generate fun, interactive learning experiences that let students put theory into practice. Virtual games can imitate real-world situations and offer realistic practice chances during training, assisting students in developing practical skills [8, 9].

Skills in developing virtual games are a valuable tool for higher education students because they give them the information and skills necessary to design, develop, and create immersive experiences in a virtual world. Furthermore, with the growing acceptance of virtual and augmented reality technologies, expertise in the development of virtual games is highly sought after in the labor market. Students with corresponding abilities will be well-positioned to take advantage of the numerous employment opportunities accessible in this profession as the field of virtual game production is anticipated to continue expanding in the upcoming years [10, 11].

Furthermore, learning in an immersive learning environment can be improved by integrating metaverse technology as a learning support tool. The use of metaverse technology in the classroom has the ability to revolutionize courses, bring teachers and students together virtually in common areas, open up new options for lifelong learning, and enhance a number of learning outcomes. This increasing the Digital Intelligence Quotient (DQ) of students given that this is a necessary characteristic for operating as part of the digital workforce in today's digital society and industry.

II. THEORETICAL FOUNDATION

A. *Metaverse Learning Experience Platform (MLXP)*

1) *The Metaverse in higher education*

The Metaverse, a term popularized by Neal Stephenson in his 1992 science fiction novel Snow Crash, refers to a virtual world that is inhabited by millions of users who interact with each other through avatars. In recent years, the concept of the Metaverse has become increasingly relevant in higher education, as the use of virtual and augmented reality technologies has grown.

The Metaverse is a term that refers to a virtual shared space where users can interact with each other and digital objects in a seamless and immersive way. This technology is becoming increasingly popular in education as it provides students with the ability to engage in immersive and interactive learning experiences [2, 12–16].

The Metaverse is an emerging technology that has the potential to revolutionize higher education by providing students with immersive and interactive learning experiences. It can be used to create virtual environments that simulate real-world scenarios, allowing students to apply theoretical concepts in a hands-on way. This can be particularly beneficial for fields such as engineering, architecture, and medicine, where students can gain practical experience in a safe and controlled environment. The Metaverse is also being used to facilitate collaboration and networking among students, faculty, and professionals [17, 18].

The Metaverse can be used to create virtual classrooms where students can interact with each other and their professors in real-time, regardless of their physical location. This can make higher education more accessible, especially for students in remote or under-served areas. Furthermore, the metaverse can be a platform for collaborative learning, research and experimentation, and for professional development opportunities [15, 19].

Additionally, the Metaverse can be utilized to develop fun, interactive, and game-based learning environments that can improve motivation and memory. In addition, the Metaverse can be utilized to build virtual museums where students can immerse themselves in the study of history by exploring historical sites and objects [10, 20, 21].

In conclusion, The Metaverse, an emerging technology, has the potential to transform higher education by giving students engaging, immersive learning opportunities. It can be used to build virtual worlds, classrooms, and learning environments based on video games, as well as chances for group learning, experimentation, and research, as well as for professional development. The Metaverse in higher education has the potential to revolutionize the way we access, experience, and collaborate within education. As virtual and augmented reality technologies continue to advance, the opportunities for the integration of the Metaverse in higher education will only continue to grow [22].

2) *Metaverse Learning Experience Platform (MLXP)*

The development of Metaverse learning experience ecosystems in higher education is a promising trend that has the potential to transform the way students learn and interact with their educational environment. It involves the integration of virtual environments and real-world education to create a seamless learning experience. One of the key drivers behind this trend is the increasing popularity of online education and the growth of virtual and augmented reality technologies. These technologies offer new and innovative ways for students to interact with their environment and with each other, allowing for a more immersive and engaging learning experience [18, 23].

The MLXP also incorporates machine learning and artificial intelligence algorithms, which can assist students receive feedback that is specifically tailored to their needs and to their learning needs. Students' motivation and involvement may rise as a result, which enhances the quality of the educational experience. A platform for cooperation and communication between students, teachers, and other stakeholders in the educational system is also provided by the ecosystem of the metaverse learning experience. This improves the social component of school and makes learning more inclusive and interesting [1, 2, 24].

B. Immersive Design Thinking

Design thinking is a human-centered approach to problem-solving and innovation that involves five stages: empathizing, defining, ideating, prototyping, and testing. In the empathizing stage, the design team seeks to understand the needs and desires of the users and gain empathy for their experiences through observation, interviews, and other methods. The defining stage involves synthesizing the insights from the empathizing stage and defining the problem to be solved. In the ideating stage, the team generates a wide range of potential solutions and explores different ways to address problems. The prototyping stage involves creating low-fidelity prototypes of the most promising solutions and testing them with users in order to get feedback and to iterate on designs. Finally, in the testing stage, the team tests the prototypes more extensively with users to gather additional feedback and refine designs further. The Metaverse is a virtual reality platform that allows users to create and interact with digital content in a shared, immersive environment. The Metaverse can be utilized in higher education to improve the design thinking process by offering a new setting for teamwork, prototyping, and testing. Higher education can use the Metaverse as a fresh and cutting-edge environment to improve the design-thinking process by giving students a place to collaborate, prototype, and test ideas [25–27].

Immersive design thinking is a brand-new, cutting-edge method of design thinking that makes use of Virtual Reality (VR), Augmented Reality (AR), and Metaverse technology. The experience of solving problems and coming up with new ideas becomes more immersive and interactive thanks to immersive design thinking. Immersive design thinking seeks to provide an intuitive, human-centered, and compelling method of solving design problems that enables users to encounter and comprehend them in novel ways. Users may interact with digital material more naturally and intuitively thanks to immersive design thinking's usage of VR and AR technology, which improves their capacity to comprehend intricate systems and issues [28, 29].

Users can work together in novel and creative ways by using immersive design thinking, which promotes a more inclusive and cooperative approach to problem-solving. For instance, people can collaborate to solve a problem with design in a Metaverse setting by sharing and expanding on one other's ideas in real-time.

C. Digital Intelligence Quotient (DQ)

In today's increasingly digitizing world, the Digital Intelligence Quotient (DQ) is a crucial skill set for undergraduate students. In order to accomplish academic, personal, and professional goals, solve problems, and engage in creative and inventive activities, one must be able to use digital technology, data, and media successfully and ethically. This is referred to as DQ. DQ includes technical and informational literacy, critical thinking, creativity, communication, cooperation, emotional intelligence, and the capacity to effectively evaluate and utilize digital information and resources [7, 30].

The DQ Institute has set a new framework to revolutionize the Environmental, Social, Governance (ESG) approach in the digital economy. The framework provides companies with tools and guidance to navigate the evolving digital landscape, focusing on responsibility, transparency, and accountability. It addresses the Metaverse, AI, big data, analytics, and the rapid digitalization of traditional businesses. This new framework consists of (1) human-centered transformation, (2) operational efficiency, (3) stakeholder safety, health, and well-being, (4) data security and system reliability, (5) digital inclusion and equity, (6) digital reputation and stakeholder engagement, (7) digital skills and human capital development, and (8) digital rights and ethics [31, 32].

The DQ Institute a new framework to revolutionize the ESG approach in the digital economy are as presented in Fig. 1:

Fig. 1. The Digital Intelligence Quotient (DQ) [32].

Developing DQ can help undergraduate students be more productive, effective communicators, and more successful in their academic and professional pursuits. It also helps prepare students for a rapidly changing digital job market, where demand for digital skills continues to grow [31, 33, 34].

D. Virtual Game Developer Skills

Virtual game development skills refer to the ability to design, develop, and create virtual games using computer software and technologies. These skills encompass a range of technical competencies including programming, 3D modeling, and animation, as well as creating and designing, involving such abilities as storytelling, game mechanics, and user experience design. Virtual game developers must also possess project management skills and an understanding of the game development process, including prototyping, testing, and post-release maintenance [9, 35]. This is in line with beliefs about the future of employment, skills and workforce strategy for the fourth industrial revolution, which relate to game developers needing specific attributes including creativity skills, problem-solving skills, project management skills, collaboration skills and adaptability skills [36, 37].

Undergraduate students who are interested in developing virtual game developer skills must possess certain characteristics that are essential for success in the field. Some of these skills and characteristics are as shown in Table I.

TABLE I: VIRTUAL GAME DEVELOPER SKILLS OF UNDERGRADUATE STUDENTS

Virtual Game Developer Skills	Characteristic
Technical skills / proficiency [10, 38, 39]	As virtual game development involves programming, it is important for undergraduate students to have a solid understanding of programming languages and other technologies used in game development. Virtual game development requires knowledge of programming languages, game engines, and software development tools.
Creativity skills [36, 37, 40, 41]	To create engaging virtual games, virtual game developers must have a creative and imaginative mind. An undergraduate game developer should have a strong imagination and be able to come up with unique ideas for games.
Attention to detail [42, 43]	Virtual game developers must pay close attention to detail in order to create a seamless and enjoyable gaming experience for players.
Problem-solving skills [36, 37, 43–45]	Virtual game development often involves overcoming technical challenges and finding creative solutions to complex problems. This requires strong problem-solving skills. It involves dealing with debugging code, so strong problem-solving skills are essential.
Project management skills [43, 45]	Virtual game developers must be able to manage large and complex projects, including scheduling, budgeting, and coordination of a team of developers.
Collaboration skills [35–37, 43–45]	Virtual game developers must be able to work effectively with others, including artists, programmers, and designers, to bring their projects to completion. Virtual Game development is often a team effort, so strong collaboration skills are necessary to work effectively with other developers.
Adaptability skills [8, 10, 37, 44]	The gaming industry is constantly evolving, and game developers must be able to adapt to new technologies and changing market trends.
Passion for gaming [10, 45, 46]	Virtual game developers must have a strong passion for gaming and be constantly seeking to improve their skills and knowledge in the field .

As can be seen from Table I, the virtual game developer skills of undergraduate students consist of the following 8 skills: technical skills/proficiency, creativity, attention to detail, problem-solving skills, project management skills, collaboration skills, adaptability skills, and passion for gaming.

The virtual game developer skills of undergraduate students are as presented in Fig. 2:

Fig. 2. The virtual game developer skills.

From the study of related literature, it was found that Designing instructional activities to develop DQ and virtual game developer skills can use the Design Thinking learning process. And using the Metaverse learning platform for game design based on Design Thinking can create an immersive learning experience for students.

III. RESEARCH OBJECTIVES AND HYPOTHESES

A. *Research Objectives*

1) To develop the Metaverse Learning Experience Platform (MLXP) for immersive design thinking.
2) To develop the immersive design thinking process on MLXP.
3) To evaluate the digital intelligence quotient (DQ) of students who use MLXP for immersive design thinking.
4) To evaluate the virtual game developer skills of students who use MLXP for immersive design thinking.

B. *Research Hypotheses*

1) Students who studied by using the MLXP for immersive design thinking had an excellent level of DQ.
2) Students who studied by using the MLXP for immersive design thinking had an excellent level of virtual game developer skills.

IV. RESEARCH METHODOLOGY

The research methodology was divided into three phases based on the research objectives.

A. *Phase 1: Development of the Metaverse Learning Experience Platform (MLXP) for Immersive Design Thinking.*

The development of the MLXP for immersive design thinking follows the System Development Life Cycle (SDLC) process [47], including:

1) Planning: During this phase, project goals, requirements, timelines, and resources are identified and documented for MLXP.
2) Analysis: In this phase, software requirements are analyzed and evaluated to determine feasibility, and to identify potential issues for MLXP.
3) Design: The design phase involves creating a detailed plan for the MLXP, including the user interface, database structure, and program specifications.

4) Implementation: This is the phase during which the MLXP is developed, and the code is written and tested.
5) Testing: The MLXP is tested to identify and fix any bugs or issues that may arise.
6) Maintenance: This phase involves ongoing support and maintenance of the MLXP to ensure that it continues to function effectively and efficiently.

B. Phase 2: Development of the Immersive Design Thinking Process on MLXP for Enhancing Digital Intelligence Quotient and Virtual Game Developer Skills

1) Synthesis of the literature related to immersive virtual technology, design thinking, and the metaverse to create an immersive design thinking process framework on MLXP, by using content analysis techniques. The tool used is the content analysis form.
2) Synthesis of the literature related to DQ and virtual game developer skills to set goals for the development of the skills and characteristics of students, by using content analysis techniques. The tool used is the content analysis form.
3) Develop design learning activities for immersive design thinking on the MLXP.
4) Evaluate the suitability and quality of immersive design thinking process on MLXP with the aid of 10 experts in immersive virtual technology, design thinking, metaverse, DQ, and virtual game developer skills. The processes' suitability assessment form was used as a 5-level approximation scale. The data was analyzed using the arithmetic mean and standard deviation.

C. Phase 3: Evaluate the Digital Intelligence Quotient and Virtual Game Developer of Students Studying Using Metaverse Learning Experience Platform for Immersive Design Thinking

1) Research variables

The independent variable is the MLXP for immersive design thinking.

The dependent variables are DQ and virtual game developer skills.

2) Population and sample groups

The population is undergraduate students from the Faculty of Science and Technology, Rajamangala University of Technology, Suvarnabhumi in the academic year 2022.

The sample group consisted of 36 undergraduate students, one classroom, were randomly selected with the use of cluster random sampling, from the Faculty of Science and Technology, Rajamangala University of Technology, Suvarnabhumi. These students were enrolled in 3-dimensional character rigging and animation, virtual reality technology, game design, multimedia technology project in the academic year 2022.

The study of the effects of the MLXP for immersive design thinking involves the following steps:

A. Preparation stage

a) Orientation: Instructors provide learning guidance using the MLXP, immersive design thinking learning activities, methods for measuring and evaluating learning, and methods for evaluating DQ and virtual game developer skills.
b) Learners conduct practical exercises using the MLXP: registration, login, avatar creation, online self-paced learning, use of an immersive virtual learning space, immersive virtual coworking space, immersive virtual presentation, immersive virtual meeting, immersive virtual exhibition, immersive virtual portfolio, homework submissions and assignments.

B. Experimental stage

The students studied by using the MLXP for immersive design thinking over two consecutive semesters of 12 weeks each, totaling 24 weeks, by implementing the learning activity plan, consisting of learning objectives, instructor's role, learner's role, instructional activity process, immersive instructional media, measurement and evaluation methods, the Hyflex learning methodology consisting of face-to-face learning in physical classrooms and Onverse (teaching and learning on MLPX), which is online immersive learning through an MLXP.

3) Evaluation stage

After students studied by using the MLXP for immersive design thinking, the evaluation was conducted as follows:

1) Evaluate the DQ in 8 areas: (1) human-centered transformation, (2) operational efficiency, (3) stakeholder safety, health, and well-being, (4) data security and system reliability, (5) digital inclusion. and equity, (6) digital reputation and stakeholder engagement, (7) digital skills and human capital development, and (8) digital rights and ethics. The evaluation involved using the DQ assessment form using 5 level scoring rubric criteria. The total possible score was 40. The data was analyzed using the arithmetic mean and standard deviation.
2) Evaluate virtual game developer skills in 8 areas: (1) technical skills/proficiency, (2) creativity, (3) attention to detail, (4) problem-solving skill, (5) project management skill, (6) collaboration skill, (7) adaptability skill, and (8) passion for gaming. The evaluation involved using a virtual game developer skills assessment form using 5 level scoring rubric criteria. The total possible score was 40. The data was analyzed by using the arithmetic mean and standard deviation.

The research methodology is presented in Fig. 3:

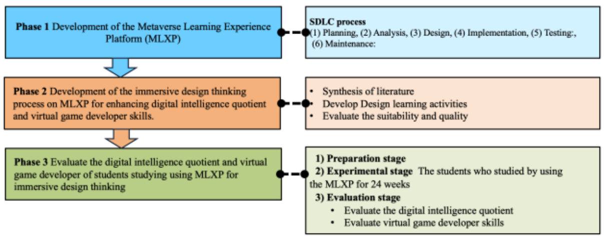

Fig. 3. The research methodology.

V. RESEARCH FINDINGS

A. The Metaverse Learning Experience Platform (MLXP) for Immersive Design Thinking

1) The components of the metaverse learning ecosystem

The metaverse learning ecosystem refers to a virtual environment that provides an immersive and interactive experience for students, combining elements of virtual reality, augmented reality, and gamification. The student can access the ecosystem through the internet. The ecosystem offers a persistent, shared, immersive environment where people can interact with each other and with digital objects. The metaverse can be used to enhance the learning experience. The components of a metaverse learning ecosystem can be synthesized as follows in Table II.

TABLE II: THE COMPONENTS OF THE METAVERSE LEARNING ECOSYSTEM

Components of the Metaverse Learning Ecosystem	Details
Virtual reality environments	These environments provide a fully immersive experience, allowing students to engage with the virtual world in a natural and intuitive way.
Augmented reality interfaces	These interfaces combine virtual elements with the real world, enhancing the learning experience, and allowing for interactive and dynamic learning opportunities.
Metaverse Learning Platform	This is an immersive and interactive environment that provides learner with access to educational resources and opportunities for interaction and collaboration in terms of learner-instructor, learner-learner (peers), and learner- content.
Gamification elements	Gamification elements, such as rewards and points systems can increase student engagement and motivation by providing a fun and interactive way to learn. The metaverse can be used to create games and simulations that teach specific skills and knowledge, providing an engaging and interactive learning experience.
Social collaboration tools	These tools allow students to work together and collaborate in real-time, fostering social connections and a sense of community.
Personalized learning experiences	Personalized learning experiences, such as adaptive learning and recommendation systems use data and analytics to provide customized learning experiences for each student, based on their strengths and weaknesses.
Virtual classrooms	The metaverse can provide a virtual environment for students to attend class, participate in discussions and group activities, and interact with their instructor and peers.
Immersive simulations	The metaverse can provide a platform for students to experience real-world scenarios and situations such as simulations of historical events or scientific phenomena, in a safe and controlled environment.
Virtual field trips	The metaverse can provide a platform for students to explore virtual representations of real-world locations such as museums, historical sites, and natural landmarks, without leaving the classroom.

2) *The components of Metaverse Learning Experience Platform (MLXP)*

An MLXP is an immersive and interactive environment that provides students with access to educational resources and opportunities for interaction and collaboration with teachers, peers, and content. The components of a virtual learning platform are shown as follows in Table III.

TABLE III: THE COMPONENTS OF MLXP

Components of MLXP	Details
Metaverse learning management system (M-LMS)	The M-LMS is the backbone of the platform, providing a centralized repository for educational content and resources, as well as tracking and assessment tools, and avatar creation.
	A M-LMS serves as the central repository for all course materials, assignments, and assessments, providing a comprehensive view of student progress.
Metaverse Content Management System (M-CMS)	A M-CMS enables instructional designers and teachers to create, upload, and manage educational content, such as videos, audio, text, and images.
Metaverse Content Delivery System (M-CDS)	The platform should provide a variety of multimedia content such as videos, images, text, and interactive simulations, to meet the needs of different learning styles.
Metaverse Personalized learning tools	Metaverse personalized learning tools use data and analytics to provide customized learning experiences for each student, based on their strengths and weaknesses.
Analytics and reporting tools	Data and analytics tools provide insights into student performance and learning progress, enabling instructors to track and improve student outcomes.
Assessment and evaluation tools	Assessment and evaluation tools allow instructors to design and administer assessments, quizzes, and exams, and to track and evaluate student progress.
Immersive collaboration tools	Immersive collaboration tools facilitate real-time interaction between students and instructors, such as through discussion forums, chat rooms, and video conferencing.
Immersive virtual learning space	In an immersive virtual learning space within the metaverse, students can interact with objects, explore environments, and communicate with other learners in real-time. The instructors can customize the virtual learning space to fit the student's specific needs and preferences. Instructors can design and create digital resources such as virtual textbooks, simulations, and multimedia presentations to provide a more engaging learning experience for students. With the use of metaverse, it is also possible to track and analyze student progress and behavior, allowing teachers to provide personalized feedback and support.
Online self-paced learning space	This is a space for students to learn by themselves through the metaverse. Students must learn individually in advance of the class from the learning materials that the teacher has prepared, including worksheets, knowledge media, teaching aids, videos, audio, text, images.
Immersive virtual meeting space	This is a space where game development students interview game players to understand the needs and preferences of such players, and the desires of the users and gain empathy for their experiences. Students also use this space for brainstorming sessions to collaborate on game design and development in all stages of the immersive design thinking process: immersive empathize, immersive define, immersive ideate, immersive prototype, and immersive test.
Immersive virtual co-working space	This is a space that students use for collaboration. Students will be able to share files and create collaborative projects as part of a group during learning activities based on the immersive design thinking process in two phases: immersive prototype, and immersive test.
Immersive virtual presentation space	This is a space that students use to present group work on game design and development to classmates and teachers in all stages of the immersive design thinking process: immersive empathize, immersive define, immersive ideate, immersive prototype. , and immersive test. The game development team presents their work, and then classmates and instructors discuss their ideas for further improvement.

Components of MLXP	Details
Immersive virtual exhibition space	This is a space that students in a group use to present their completed work. The work is displayed for classmates, teachers, and gamers to allow them to view the work immersively through the avatars in the metaverse platform.
Immersive virtual portfolio space	This is a space where each student can store their own game development work from learning activities based on the immersive design thinking process in an individual immersive virtual portfolio.

The components of the components of Metaverse Learning Experience Platform (MLXP) is presented in Fig. 4.

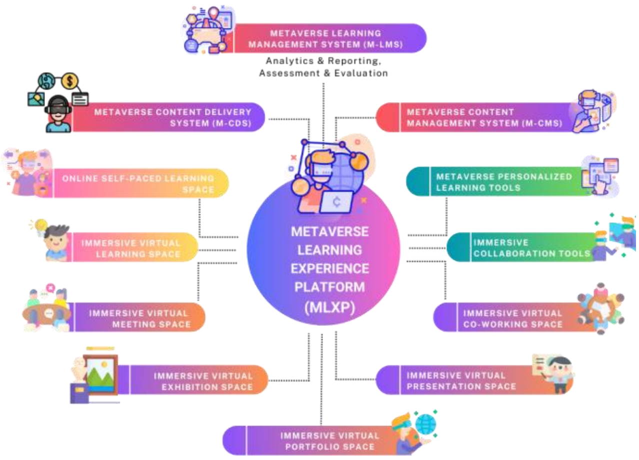

Fig. 4. The components of Metaverse Learning Experience Platform (MLXP).

The System Architecture of Metaverse Learning Experience Platform is presented in Fig. 5.

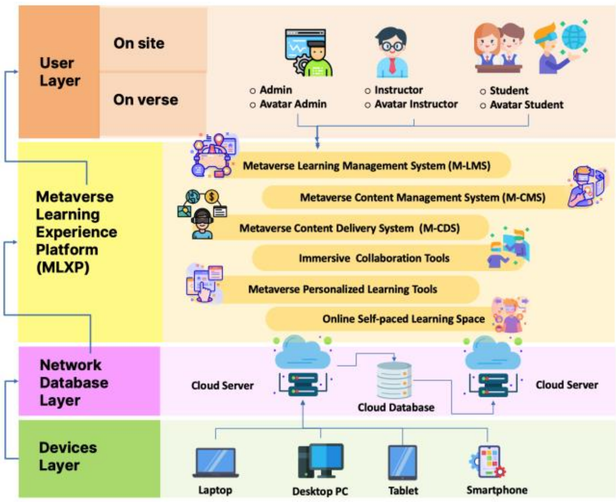

Fig. 5. The system architecture of Metaverse Learning Experience Platform (MLXP).

The implementation of MLXP should prepare the infrastructure system, including (1) Devices for MLXP use consisting of laptops, desktop PCs, tablets, and smartphones, (2) Network database for connecting to MLXP through devices consisting of a cloud server, database, cloud server, (3) MLXP includes the Metaverse Learning Management System (M-LMS), Metaverse Content Management System (M-CMS), Metaverse Content Delivery System (M-CDS), immersive collaboration tools, metaverse personalized learning tools, and online self-paced learning space, (4) User, MLXP users consist of admin, avatar admin, instructor, avatar instructor, student, and avatar student.

The immersive design thinking process on Metaverse Learning Experience Platform (MLXP) is presented in Fig. 6

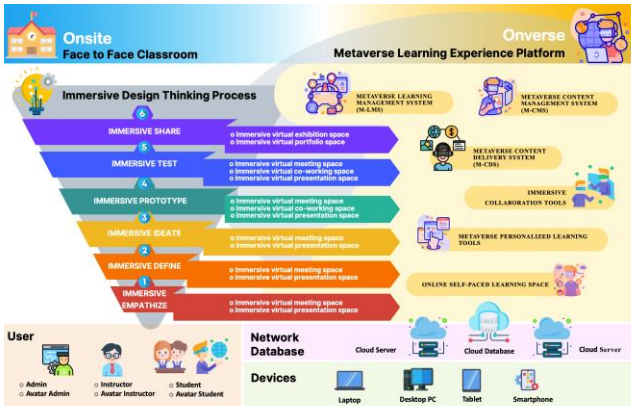

Fig. 6. The immersive design thinking process on Metaverse Learning Experience Platform (MLXP).

3) *The immersive design thinking process on MLXP*

TABLE IV: THE IMMERSIVE DESIGN THINKING PROCESS ON MLXP

Immersive Design Thinking Process	Metaverse Learning Ecosystem Platform (MLXP)	Learning Activities
Immersive Empathize	○ immersive virtual meeting space ○ immersive virtual presentation space	The game developer seeks to understand the needs, desires and preferences of players. In this way they gain empathy for user experiences through observation, interviews, and other methods. In a metaverse, game designers can create virtual simulations that allow players to experience the game mechanics and gameplay in a more realistic way, providing designers with valuable feedback.
Immersive Define	○ immersive virtual meeting space ○ immersive virtual presentation space	The game designers use insights from the empathize stage to determine the problem they are trying to solve. In a metaverse, game designers can collaborate with players in real-time to refine their understanding of the problem and develop a shared vision for the game.
Immersive Ideate	○ immersive virtual meeting space ○ immersive virtual presentation space	The game designers generate a wide range of potential solutions and explore different ways to address the problem. They create the ideas for game mechanics and gameplay. In a metaverse, game designers can use virtual whiteboards and other collaborative tools to brainstorm and refine ideas with players in real-time.
Immersive Prototype	○ immersive virtual meeting space ○ immersive virtual co-working space ○ immersive virtual presentation space	The game developers create rough drafts of potential game mechanics and gameplay. The team involves creating low-fidelity prototypes of the most promising solutions and testing them with users in order to obtain feedback and iterate on the designs. In a metaverse, game designers can use 3D modeling tools to create

Immersive Design Thinking Process	Metaverse Learning Ecosystem Platform (MLXP)	Learning Activities
		virtual prototypes that players can interact with and provide feedback on.
Immersive Test	○ immersive virtual meeting space ○ immersive virtual co-working space ○ immersive virtual presentation space	The game developers test the prototypes more extensively with users to gather additional feedback and refine the designs further. The team evaluate and refine their prototypes based on feedback from players. In a metaverse, game developers can conduct user testing in a virtual environment, allowing for more efficient and cost-effective testing.
Immersive Share	○ immersive virtual exhibition space ○ immersive virtual portfolio space	The team craft and share the story and virtual game developed with colleagues, classmates, instructors and game players via the metaverse platform.

4) *The assessment results of the MLXP for immersive design thinking*

a) The assessment results of the suitability of the MLXP components are as shown in Table V.

TABLE V: RESULTS OF ASSESSMENT OF THE SUITABILITY OF THE COMPONENTS OF MLXP (*N = 10*)

Components of MLXP	Evaluation results		
	Mean	*S.D.*	Suitability level
Metaverse Learning management system (M-LMS)	4.40	0.49	Good
Metaverse Content Management System (M-CMS)	4.50	0.67	Excellent
Metaverse Content Delivery System (M-CDS)	4.70	0.46	Excellent
Metaverse Personalized learning tools	4.70	0.46	Excellent
Analytics and reporting tools	4.40	0.80	Good
Assessment and evaluation tools	4.60	0.49	Excellent
Immersive collaboration tools	4.90	0.30	Excellent
Immersive virtual learning space	4.70	0.46	Excellent
Online self-paced learning space	4.90	0.30	Excellent
Immersive virtual meeting space	4.90	0.30	Excellent
Immersive virtual co-working space	5.00	0.00	Excellent
Immersive virtual presentation space	4.90	0.30	Excellent
Immersive virtual exhibition space	5.00	0.00	Excellent
Immersive virtual portfolio space	4.60	0.66	Excellent
Overall	**4.73**	**0.51**	**Excellent**

From Table V, the overall suitability of the components of MLXP were found to be excellent (*Mean* = 4.73, *S.D.* = 0.51). When considering each aspect, it was found that the immersive virtual co-working space, and immersive virtual exhibition space were the most appropriate (*Mean* = 5.00, *S.D.* = 0.00), followed by the immersive collaboration tools, online self-paced learning space, immersive virtual meeting space, and immersive virtual presentation space (*Mean* = 4.90, *S.D.* = 0.30), and by metaverse content delivery system, metaverse personalized learning tools, and immersive virtual learning space (*Mean* = 4.70, *S.D.* = 0.46), respectively.

b) The assessment of the suitability of the immersive design thinking process on MLXP are as shown in Table VI.

TABLE VI: RESULTS OF ASSESSMENT OF THE SUITABILITY OF THE IMMERSIVE DESIGN THINKING PROCESS ON MLXP (*N = 10*)

Immersive design thinking process on MLXP	Evaluation results		
	Mean	*S.D.*	Suitability level
Step 1: Immersive Empathize	4.90	0.30	Excellent
Step 2: Immersive Define	5.00	0.00	Excellent
Step 3: Immersive Ideate	5.00	0.00	Excellent
Step 4: Immersive Prototype	4.90	0.30	Excellent
Step 5: Immersive Test	4.70	0.64	Excellent
Step 6: Immersive Share	5.00	0.00	Excellent
Overall	**4.92**	**0.33**	**Excellent**

From Table VI, we can see that the immersive design thinking process on MLXP scored highest in terms of overall suitability (*Mean* = 4.92, *S.D.* = 0.33). When considering each aspect, it was found that step 2: immersive define, step 3: immersive ideate, and step 6: immersive share, were the most appropriate (*Mean* = 5.00, *S.D.* = 0.00), followed by the step 1: immersive empathize, and step 4: immersive prototype (*Mean* = 4.90, *S.D.* = 0.30), and finally step 5: immersive test (*Mean* = 4.70, *S.D.* = 0.64), respectively.

The Metaverse Learning Experience Platform (MLXP) is presented in Fig. 7:

Fig. 7. The Metaverse Learning Experience Platform (MLXP).

B. *The Assessment Results with Regard to the Digital Intelligence Quotient of Students Studying Using MLXP for Immersive Design Thinking*

The assessment results of the DQ of students who studied by using MLXP for immersive design thinking are shown in Table VII.

TABLE VII: RESULTS OF THE DIGITAL INTELLIGENCE QUOTIENT OF STUDENTS STUDIED USING MLXP FOR IMMERSIVE DESIGN THINKING (*N = 36*)

Digital intelligence quotient	Evaluation results		
	Mean	*S.D.*	Level
Human-Centered Transformation (5)	4.56	0.50	Excellent
Operational Efficiency (5)	4.67	0.47	Excellent
Stakeholder Safety, Health, and Well-Being (5)	4.53	0.60	Excellent
Data Security and System Reliability (5)	4.64	0.58	Excellent
Digital Inclusion and Equity (5)	4.47	0.73	Good
Digital Reputation and Stakeholder Engagement (5)	4.72	0.45	Excellent
Digital Skills and Human Capital Development (5)	4.42	0.79	Good
Digital Rights and Ethics (5)	4.78	0.42	Excellent
Overall	**4.60**	**0.59**	**Excellent**
Total (40)	**36.78**	**3.04**	**Excellent**

From Table VII, we can see that the undergraduate students' DQ was at the excellent level in terms of overall suitability (*Mean* = 4.60, *S.D.* = 0.59), and the total score was also at the excellent level (*Mean* = 36.78, *S.D.* = 3.04). When considering particular aspects, it was found that digital rights and ethics was deemed to be the most appropriate (*Mean* = 4.78, *S.D.* = 0.42), followed by digital reputation and stakeholder engagement (*Mean* = 4.72, *S.D.* = 0.45), and operational efficiency (*Mean* = 4.67, *S.D.* = 0.47), respectively.

C. The Assessment of the Virtual game Developer Skills of Students Using MLXP for Immersive Design Thinking

The assessment of the virtual game developer skills of students who studied using MLXP for immersive design thinking are as shown in Table VIII.

TABLE VIII: RESULTS OF THE VIRTUAL GAME DEVELOPER SKILLS OF STUDENTS USING MLXP FOR IMMERSIVE DESIGN THINKING *(N = 36)*

Virtual game developer skills	Evaluation results		
	Mean	*S.D.*	Level
Technical skills/proficiency (5)	4.75	0.43	Excellent
Creativity skills (5)	4.86	0.35	Excellent
Attention to detail (5)	4.53	0.60	Excellent
Problem-solving skills (5)	4.67	0.58	Excellent
Project management skills (5)	4.39	0.76	Good
Collaboration skills (5)	4.92	0.28	Excellent
Adaptability skills (5)	4.42	0.79	Good
Passion for gaming (5)	4.50	0.69	Excellent
Overall	**4.63**	**0.62**	**Excellent**
Total (40)	**37.03**	**2.41**	**Excellent**

From Table VIII, we can see that the undergraduate students' virtual game developer skills were at an excellent level in terms of overall suitability (*Mean* = 4.63, *S.D.* = 0.62), as was the total score (*Mean* = 37.03, *S.D.* = 2.41). When considering each individual aspect, it was found that collaboration skills were the most appropriate (*Mean* = 4.92, *S.D.* = 0.28), followed by creativity skills (*Mean* = 4.86, *S.D.* = 0.35), and technical skills/proficiency (*Mean* = 4.75, *S.D.* = 0.43), respectively.

VI. DISCUSSION

M-LMS, M-CMS, M-CDS, metaverse personalized learning tools, analytics and reporting tools, assessment and evaluation tools, immersive collaboration tools, immersive virtual learning space, online self-paced learning space, immersive virtual meeting space, immersive virtual co-working space, immersive virtual presentation space, immersive virtual exhibition space, and immersive virtual portfolio space are the 14 components that make up a fully developed MLXP. Immersive empathizing, immersive defining, immersive ideating, immersive prototyping, immersive testing, and immersive sharing are the six processes that make up the application of MLXP to the immersive design thinking process. Students may create a great DQ because of this. This suggests that the Metaverse has the ability to alter higher education by promoting cooperation, enhancing accessibility, and generating immersive and compelling learning experiences [35, 36].

Students can build exceptional game development abilities through the immersive design thinking approach. This is due to the fact that using the Metaverse for the design thinking process can benefit undergraduate students in terms of their ability to develop video games, including by fostering creative problem-solving, enhancing retention and engagement, enhancing collaboration and communication, providing realistic feedback, fostering creativity, enhancing accessibility, and developing technical skills and proficiency [37–40]. Educators may provide students with creative and efficient learning possibilities by implementing immersive design thinking techniques.

VII. CONCLUSION

Design thinking is a human-centered approach to problem-solving and innovation that emphasizes empathy, experimentation, and iteration. The Metaverse is a virtual reality platform that allows users to create, and to interact with digital content in a shared, immersive environment. In higher education, the Metaverse can be used to enhance the design thinking process by providing a new space for collaboration, prototyping, and testing. One way to integrate the Metaverse into the design thinking process is to use it as a tool for creating virtual environments for collaboration and ideation. By working together in a shared virtual space, students can share and build on each other's ideas in a more effective way than before. This helps foster a more collaborative and creative learning experience. Similarly, the Metaverse can be used as a platform for testing and evaluating prototypes. By creating virtual representations of prototypes, students can simulate real-world scenarios and evaluate the effectiveness of their designs in a controlled, safe environment. This can help students understand how their designs would perform in the real world, and allow them to make informed decisions about how to improve them. According to the research finding, the application of immersive virtual learning spaces within the Metaverse now offers a unique and innovative way to enhance traditional classroom learning, providing a more engaging and interactive experience for students in higher education institutions, an approach that will become increasingly important in the future.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Naphong Wannapiroon conducted the research by designing research frameworks, designing research methodology, analyzing data, developing MLXP: Metaverse Learning management system (M-LMS), a Metaverse Content Management System (M-CMS), a Metaverse Content Delivery System (M-CDS), assessment and evaluation tools, immersive collaboration tools, an immersive virtual learning space, an immersive design thinking process, a digital intelligence quotient, and a virtual game developer skills assessment form, discussing the findings, writing and reviewing the paper. Sorrachai Shawarangkoon conducted the research by developing MLXP: metaverse personalized learning tools, analytics and reporting tools, an online self-paced learning space, an immersive virtual learning space, developing an immersive design thinking lesson plan, collecting data, and preparing the data for analysis. Chatchada Chawarangkoon conducted the research by designing research frameworks and designing research methodologies, developing MLXP: an immersive virtual presentation space, an immersive virtual exhibition space, and Atis kucharoenthavorn conducted the research by developing MLXP: an immersive virtual meeting space, an immersive virtual co-working space, and an immersive virtual portfolio space. Panita Wannapiroon conducted the research by designing research frameworks, editing the paper, and reviewing MLXP. All authors had approved the final version.

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