Immersive Digital Learning Experience Design for Extended Reality Community of Practice to Enhance Educational Digital Game Design Skills

Parwapun Kamtab* and Sawanan Dangprasert

Department of Educational Technology and Information, Faculty of Technical Education, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

Email: parwapun.k@fte.kmutnb.ac.th (P.K.); sawanan.d@fte.kmutnb.ac.th (S.D.)

*Corresponding author

Manuscript received January 15, 2025; revised February 11, 2025, accepted February 25, 2025; published July 8, 2025

***Abstract*—This study investigates the creation of immersive digital learning experiences within an Extended Reality Community of Practice (XR-CoP) to improve educational digital game design skills. Employing a one-group quasi-experimental design, the study integrated innovative technology and innovative learning experiences in digital education to develop and refine an XR-supported learning ecosystem. A total of 25 master's learners from digital technology programs took part in structured activities that focused on experiential learning, knowledge sharing, and iterative skill development. The evaluation results show that the proposed learning model was highly efficient (mean = 4.77, Standard Deviation (*S.D.*) = 0.30), indicating its suitability for implementation. Furthermore, the XR-CoP environment received the highest rating in key areas such as learner engagement (mean = 4.90, *S.D.* = 0.22) and content appropriateness (mean = 4.80, *S.D.* = 0.27). The assessment of learners' digital game design skills revealed significant proficiency, especially in sound design (mean = 4.71, *S.D.* = 0.45) and interactive design (mean = 4.51, *S.D.* = 0.55). Furthermore, correlation analysis revealed a strong positive relationship between active participation in the community and skill development ($r = 0.947$, $p < 0.001$), highlighting the importance of collaborative learning. These findings highlight the efficacy of XR-CoP in connecting theoretical knowledge with practical applications. The model promotes the development of essential skills like storytelling, instructional design, and user-centered game development. This study helps to advance immersive learning frameworks and provides practical insights for educators and professionals looking to improve digital game design skills through community-based, technology-driven learning experiences.**

***Keywords*—immersive digital learning, learning experience design, extended reality, community of practice, educational digital game design skills**

I. Introduction

The creative industry in the software sector is considered to have high potential for growth, especially in the industries of games and animation, since technology has continuously improved, and Thailand has supportive policies related to the digital industry. Skill development related to educational digital game design has gained increased interest, as an educational digital game could improve learning and transform the processes in education into more engaging and enjoyable experiences [1]. Learners can conceptualize key, complex ideas and be engaged in the process of gaining key skills: critical thinking, solving problems, and collaborating. Serious games, thereby, play a central role in reforming methodologies across educational sectors in these changing, technological times [2].

In addition, serious digital educational games provide opportunities for individualized learning and meet the flexible needs of learners for the delivery of learning experiences that may effectively correspond to the inclinations and aptitudes of individuals [3]. Educational digital games also cultivate important social and communicational skills that are necessary in today's world of interdependence. Learners can practice collaboration by completing in-game tasks and solving problems collectively in a friendly and informal environment [4]. These are highly valued in future work contexts emphasizing teamwork and applying diverse skills to address complex challenges. It is, therefore, very important that digital games are designed in such a way that social skill development is integrated with technical expertise.

In as much as there is an increasing interest in educational digital game design, the teaching and learning of it present various challenges, which include unsuitable curricula, a shortage of specialized professionals, and an overemphasis on technical skills such as graphic design and programming rather than effective learning design [5]. There is a need to develop curricula that integrate various types of knowledge and skills for increasing the capacity to design educationally effective digital games. It is also necessary that such a learning design deepen expertise on the use of technology by integrating real-world experiences so meaningful and sustainable learning can be assured. Furthermore, this will enable the enhancement of skills in the design of responsive and interactive game content so that digital games become truly effective in bringing forth permanent learning outcomes.

This curriculum design in integrating essential skills for educational digital game design should focus on creativity, collaboration, and systemic problem-solving. Such a curriculum, emphasizing the different skills, will eventually help the learners to develop serious digital games to meet the needs of the diverse learner groups [6]. Also, such curricula that encourage experimentation with different technologies and educational media will help the development of confidence and skills in the designing of effective games. However, curriculum design should consider accessibility strategies, such as utilizing platforms that support lower-spec devices, developing flexible learning materials, and incorporating open educational resources that are freely accessible. These approaches will help ensure that learners with limited access to devices or technology can engage with and develop skills in digital game design on an equitable

basis.

The design of immersive digital learning experiences represents an innovative approach to the creation of valuable and engaging learning environments. These innovative reality technologies, such as virtual reality, augmented reality, and mixed reality, enhance deep learning, combining real-world and digital worlds in a way that makes knowledge acquisition more effective and interesting [7]. The design for the creation of digital experiences that permit engagement and interaction with content for facilitation is very important toward worthwhile learning, especially those experiences that technology can effectively re-create as realistic or virtual. Learners would then be able to put in context information that seems so complex or abstract if they interact firsthand with immersive virtual learning environments designed to support their learning.

Engagement and interaction in immersive learning environments promote meaningful learning capable [8] of connecting effectively to life's real experiences. It also promotes better understanding of information that may be complex or abstract on the part of the learners. The virtual technologies enable the learners to visualize realistic scenarios and go through experiences that promote better learning and long-term retention. Immersive learning design fosters an intimate relationship between the learner and the content, which results in relevant learning connected to past learning experiences [9].

A related essential mechanism is the extended reality community of practice creation as another means of collaborative learning through the interactions in that community. Learners learn from each other and can share tacit knowledge, leading to meaningful and sustainable learning outcomes. These community help create an atmosphere for sharing and collaboration that enables learners to learn from one another and build relationships for enhanced skill development. A supportive and engaging community will motivate learners to be confident in improving their skills, thus fostering meaningful and sustainable learning [10].

Extended reality community of practice also provide spaces where learners can co-create knowledge through collaborative projects or tasks. Working together in virtual contexts allows learners to practice communication, planning, and teamwork—very important skills in modern workplaces. Community building for knowledge exchange and collaboration gives confidence in learning and self-development, making the learners feel part of a meaningful learning society [11].

Thus, developing immersive digital learning experiences with various dimensions in the extended reality community of practice would present a promising and innovative approach for developing skills in digital game design for educational uses among learners, as through this, the learners may apply the said skills expressively and efficiently in day-to-day contexts. To generate meaningful learning, making use of technology becomes the need of the hour, in which a very diversified approach would meet the learning needs and enhance a learning society for sustainability regarding knowledge and skills development. Furthermore, the development of an online learning community based on collaboration and mutual support enhances learners for long-term creative skills. Educational systems that are flexible, learner-centered, linked, and supportive of individual learner contexts and personalized learning motivation inspire learners to apply what they learn in solving complex real-world problems. The development of flexible learning approaches that focus on learner engagement is a key driver for sustainable and effective educational transformation.

II. Objectives of the Research

1) To develop a model for designing immersive digital learning experiences for extended reality community of practice to enhance educational digital game design skills.
2) To develop an extended reality community of practice for facilitating immersive digital learning experiences.
3) To study the impact of enhancing learners' educational digital game design skills through participation in an extended reality community of practice.

III. Literature Review

A. Immersive Digital Learning

Immersive digital learning is an approach to learning using virtual reality technologies for environment simulation, creating virtual social settings that embed pedagogical principles [12, 13]. Also known as sociotechnical-pedagogical usability, this approach gives priority to learning through social interaction and collaborative activities. In designing such learning experiences, there are three critical dimensions that need to be considered: 1) Socio-technical usability is related to "social presence," or the use of technology that provides a greater sense of social presence. 2) Socio-pedagogical usability refers to the usage of pedagogical strategies that foster social interaction. 3) Technical-pedagogical usability refers to the way technology may support pedagogical practices effectively [14–17]. These dimensions can be effectively integrated if the design allows for usability that caters to the wide varieties of learning content and processes. It is about offering learners freedom to interact and bridge seamlessly between the real and virtual worlds, all at a high level of realism. Realism will play a very important role in provoking and sustaining interest in the learning activities. Most importantly, the technology should facilitate an overall strong sense of presence that provides an accurate impression of personality, attitude, and behavior in the virtual setting.

B. Learning Experience Design

Learning Experience Design (LXD) emphasizes the development of educational experiences that prioritize the learner. It integrates principles from User Experience design (UX design) and instructional design to render learning both effective and interesting. Learning experience design fundamentally involves comprehensively understanding learners, their wants, objectives, and obstacles, and creating environments that facilitate the acquisition of essential skills and knowledge. Learning experience design adopts a deliberate methodology, designing experiences that resonate with learners and correspond with their objectives. It encompasses more than just substance; it involves the ambiance, the instruments, and the endeavors that inspire and

invigorate [18, 19].

Learning experience design leverages technology to craft captivating educational resources and devises activities that foster learner growth, guaranteeing the perceived importance and relevance of the gained knowledge in practical scenarios. Learning experience design's versatility is what renders it extremely valuable [20]. It acknowledges that each learner is distinct, necessitating adaptable learning designs that can evolve according to their requirements. Through innovative technological integration, learning experience design maintains learning as fresh, engaging, and pertinent, cultivating curiosity and sustained interest [21]. However, learning experience design extends beyond mere involvement. It also seeks to establish an emotional bond between the learner and the educational process. When learners sense a connection to their studies, they are more inclined to remain motivated and engaged. By emphasizing this relationship, learning experience design enhances education and training to be both effective and transformative, enabling learners to attain significant, enduring outcomes.

C. Extended Reality Learning

Extended Reality (XR) integrates Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) to develop dynamic, immersive educational settings. By transcending conventional approaches, such as lectures and textbooks, extended reality enables learners to directly engage with simulated knowledge, thereby enhancing the learning experience's engagement and efficacy. This transition fosters enhanced comprehension and more significant educational results [22]. A notable advantage of extended reality is its capacity to provide virtual field trips, allowing learners to investigate locations and activities that may otherwise be inaccessible. These virtual environments facilitate the comprehension of abstract concepts and offer learners the opportunity to practice and enhance their skills in a secure, regulated context [23, 24].

Extended reality promotes active learning by positioning learners at the core of the experience. Rather than passively receiving information, learners can engage in experimentation, exploration, and problem-solving within authentic contexts [25–27]. This experiential method cultivates critical thinking, problem-solving, and decision-making skills. Learners can experiment with concepts, observe immediate outcomes, and build confidence through this iterative process. Furthermore, extended reality facilitates individualized learning pathways [28, 29]. It accommodates distinct learning styles and tempos, providing a flexibility frequently absent in conventional methods. Learners can review difficult content, engage in activities repeatedly until they achieve confidence, and advance at their own pace. As learners progress, extended reality can present increasingly intricate scenarios, maintaining a stimulating and difficult learning experience while promoting sustained growth and retention.

D. Community of Practice

A Community of Practice (CoP) is a group of individuals with shared interests in a specific domain who come together to exchange knowledge, share experiences, and collaboratively build expertise. These groups, whether formal or informal, focus on learning through social interaction, member collaboration, and engagement with real-world scenarios. In educational contexts, community of practice is extensively used to promote meaningful learning by creating environments for learners to engage in discussions, exchange perspectives, and collaboratively address challenges, thereby enhancing learning outcomes [30, 31].

In educational and training settings, community of practice serve as a bridge between theoretical understanding and practical application. Members gain practical skills relevant to their circumstances by sharing work-related insights and experiences. Unlike traditional methods that rely solely on expert-led teaching, community of practice emphasize peer learning, collaborative skill-building, and mutual support. This framework fosters an environment where learning is ongoing, relevant, and engaging [32, 33].

The concept of community of practice is grounded in social learning theory, which asserts that learning is most effective through active participation and collaborative practice rather than passive knowledge absorption. Members of a community of practice work together to develop domain-specific knowledge through discussions, hands-on experimentation, and reflection on experiential learning [34, 35]. This approach not only facilitates the exchange of information but also supports its continuous refinement and adaptation to meet diverse needs and contexts.

Incorporating a community of practice into learning and training frameworks goes beyond simple information and skill dissemination. It cultivates a culture of collaboration and reciprocal learning. Members refine their skills through cooperative problem-solving, innovative thinking, and active engagement. These experiences prepare individuals to apply their knowledge effectively in practical settings. Additionally, fostering collaboration and knowledge sharing within a community of practice drives the creation of new ideas and innovations that benefit organizations and community alike.

E. Educational Digital Game Design Skills

Educational digital game design is a process requiring diverse skills to create games that are both engaging and effective in promoting learning. Key skills for designing educational games include setting clear and measurable learning objectives, analyzing the needs of the target audience, and creating content that aligns appropriately with the curriculum. Choosing the right game platform that suits the users and learning objectives is another essential factor that enhances the effectiveness of the game [36–38].

Developing educational digital games must also consider User Experience design (UX design), ensuring that the game is intuitive and not overly complex. This reduces learning barriers and allows learners to focus fully on the educational content. Employing interactive design principles, such as allowing players to make choices within the game, answer questions, or solve problems in simulated scenarios, can increase engagement and make learners feel integrated into the game [39–41].

Additionally, creativity plays a significant role in designing educational games. The design process should address the needs and experiences of players to ensure the game is captivating, enjoyable, and genuinely supports learning [42, 43]. This comprehensive approach ensures that

the game design encompasses all dimensions and successfully achieves its learning objectives. Ultimately, these efforts contribute to the development of educational games that are valuable and effective in fostering meaningful and sustainable learning experiences.

IV. Research Methodology

The research methodology was divided into three phases and five steps based on the research objectives as follows:

A. Phase 1: Development of a Model for Immersive Digital Learning Experience Design for Extended Reality Community of Practice to Enhance Educational Digital Game Design Skills

Step 1: Defining learning objectives

1) Define clear learning objectives, analyze learners' needs and prior knowledge, and consider their requirements and basic skills to design appropriate and inclusive learning experiences for all target groups.
2) Study the concepts and theories of digital game design for education. Explore practical design principles and interaction mechanisms that can enhance learners' motivation for learning.
3) Analyze the role of game elements in influencing learner satisfaction, learning effectiveness, and engagement.
4) Identify key skills in digital game design by integrating learning principles such as learning design, graphic design, storytelling design, sound design, and interactive design. Additionally, leveraging digital tools and technologies enables developers to design and refine game elements to align effectively with learning objectives and learners' needs.

Step 2: Synthesize the conceptual framework

Based on the learning objectives, the researcher studied theoretical concepts to design immersive digital learning experiences for the extended reality community of practice. This process aims to create a conceptual framework for planning and carrying out the research. The framework links pertinent theories and concepts, synthesizing components within each of the following topics:

1) Immersive digital learning consists of high interactivity, adaptive learning, collaborative interaction, multimodal communication, and immediate feedback.
2) Learning experience design consists of understanding learners, learner-centeredness, personalization, instructional strategy, and user experience.
3) Extended reality learning consists of mixed reality, user interaction, hardware equipment, virtual environment design, content, and learning materials.
4) Community of practice consists of practices and activities, experience sharing, expert involvement, engagement and support, and feedback mechanisms.

Step 3: Developing a learning process

The development of a learning process for the extended reality community of practice emphasizes designing learner-centered experiences. The structure and process align with the goals to ensure effectiveness. This process includes five steps: preparation stage, hands-on learning, learning community, reflection and iteration, and practical skills assessment, as shown in Table 1.

Table 1. The results of a learning process

Learning Process	Synthesize a Learning Process			
	Immersive Digital Learning [8, 11–16]	**Learning Experience Design [17–20]**	**Extended Reality Learning [21–29]**	**Community of Practice [9, 10, 30–34]**
1. Preparation Stage	- Adaptive Learning	- Personalization - User Experience	- Digital Learning	-
2. Hands-on Learning	- High Interactivity	- Instructional Strategy	- Content and Learning Materials	-
3. Learning Community	- Collaborative Interaction - Multimodal Communicate	- Learning Activities	- Mixed Reality - Virtual Environment Design	- Experience Sharing - Engagement and Support
4.Reflection and Iteration	- Immediate Feedback	- Research and Iteration	- User Interaction	- Expert Involvement - Feedback Mechanisms
5. Practical Skills Assessment	-	-	-	- Practices and Activities

After defining the learning objectives, synthesizing the conceptual framework, and designing the learning activities, the learning model was developed and evaluated for its suitability in terms of components and practical implementation. The evaluation encompassed the conceptual framework, learning process, and learning outcomes.

The model evaluation was conducted by five experts in the field of educational technology using the Learning Model Quality Evaluation Form. This tool was used to assess the quality of the model based on theoretical validity, completeness of components, and practical applicability, utilizing a five-point Likert scale.

This research explores the design of an immersive digital learning experience within an extended reality community of practice to enhance educational digital game design skills. The study integrates innovative technology and innovative learning experiences in digital education to develop and refine an immersive learning framework. The novelty of this research lies in its systematic approach to designing an XR-supported learning ecosystem, where learners engage in collaborative, experiential, and iterative game design processes within a virtual community of practice. This contributes to the field by providing a scalable instructional model that bridges immersive technologies with authentic, situated learning, offering practical guidelines for educators and designers to implement XR-based learning environments effectively.

B. Phase 2: Development of Extended Reality Community of Practice for Facilitating Immersive Digital Learning Experiences

Step 4: Developing learning materials

The development of an extended reality community of practice follows the System Development Life Cycle (SDLC),

consisting of the following steps:

Planning and requirement analysis: The goals of the extended reality community of practice are defined by considering multiple dimensions relevant to the target users. Input is gathered from key stakeholders, including learners, educators, and digital technology experts, ensuring that the design and development approach meets the users' needs and contextual requirements effectively.

Media design: This step emphasizes structuring the extended reality community of practice by integrating User Experience and User Interface (UX/UI) design to create an intuitive and engaging user experience. The appropriate platform is selected to suit the learning context. The learning materials are developed in a microlearning format, encompassing diverse media types such as digital books, infographics, motion graphics, and interactive videos. These resources are designed to provide users with efficient access to immersive content and foster interaction.

Development and testing: The extended reality community of practice is created and developed based on the predefined framework, incorporating VR, AR, or MR technologies to deliver realistic and immersive learning experiences. The system undergoes rigorous testing to evaluate its design quality, content appropriateness, and technological usability. A panel of five digital technology experts conducts the evaluation using a mixed-method approach of qualitative and quantitative analyses. This process ensures the content and user experience align with established standards and identifies potential issues for improvement. The results provide a comprehensive and reliable assessment of the extended reality community of practice's performance.

Deployment: The extended reality community of practice is introduced for real-world application. A pilot group is initially engaged to assess usability and ensure suitability before scaling to a broader audience. Training sessions are also organized for learners to enhance their understanding and effective use of the system.

Maintenance: Continuous support is provided to address potential issues during the extended reality community of practice's usage. Regular updates and enhancements to content and features are implemented based on user feedback. This ensures the community remains up-to-date, adapts to changing contexts, and continues to meet user needs effectively.

C. Phase 3: Study the Impact of Enhancing Educational Digital Game Design Skills Among Learners Engaged in Extended Reality Community of Practice

Step 5: Studying practical skills

This study aims to investigate the outcomes of enhancing learners' skills in designing educational digital games through participation in an extended reality community of practice. The focus is on collaborative learning within immersive virtual environments. Skill development encompasses design, creativity, practical application, and the use of digital technologies. The details are as follows:

1) Population and sample groups

The population consists of graduate students enrolled in the Faculty of Education. The sample includes 25 master's degree students majoring in digital technology with a background in digital media design, selected through purposive sampling.

2) Research variables

The independent variable is immersive digital learning experience design for the extended reality community of practice.

The dependent variables are educational digital game design skills among learners engaged in an extended reality community of practice.

3) The duration of the study

The experiment was conducted in the first semester of the academic year 2024 and lasted for one academic year.

4) Research design

The study used a one-group quasi-experimental design to assess participants' skill development in a community of practice. This design was appropriate as it allowed for a thorough evaluation of educational digital game design skills before and after the experimental period, without the constraints of a control group. By tracking changes in skill development over time, the study effectively investigated the impact of an immersive digital learning experience in a real-world educational setting.

5) Research instrument

The data collection tools for this study included a performance evaluation tool for the community of practice and an assessment tool for educational digital game design abilities. To improve their effectiveness, these instruments included a five-point Likert scale. To ensure the instruments' validity, five educational measurement and evaluation experts assessed the Item Objective Congruence index (IOC). Each item was assigned an IOC score, with a value of 0.50 indicating adequate content validity. However, there were suggestions for improving the wording of specific items to increase clarity and reduce the possibility of ambiguity in interpretation. Furthermore, examples were suggested for some items to help respondents understand the context of the questions. To ensure reliability, a pilot study was conducted with a sample group representative of the target population. Cronbach's alpha coefficient was used to determine the internal consistency of the Likert-scale items; a value greater than 0.70 indicates satisfactory reliability. The reliability test yielded a Cronbach's alpha coefficient of 0.85, indicating that the instrument has high internal consistency and reliability.

6) Experimental procedure

Step 1. Explain the structure of activities and access to the integrated extended reality community of practice for designing immersive digital learning experiences.

Step 2. Engage learners in immersive digital learning experiences focused on educational digital game design.

Step 3. Facilitate learner participation in activities within the integrated extended reality community of practice. Practice through utilizing Unity game engine software for the development of 2D and 3D educational games. In addition, Adobe Photoshop and Illustrator are used for designing UI, UX, and graphic elements of the game. These activities include individual and group tasks to exchange experiences and foster collaborative learning.

Step 4. Assess practical skills related to hands-on activities by analyzing essential knowledge and skills, identifying

strengths, and identifying areas for improvement to enhance digital game design skills.

Step 5. Support knowledge sharing and collaborative skill development within the community.

Step 6. Evaluate the outcomes of educational digital game design skills by examining the effectiveness of learning-promoting activities.

Step 7. Monitor and analyze the development of practical skills and game design skills using data from evaluations conducted during and after the experiment.

7) Data collection

a) Work performance assessment

The assessment of work performance focuses on evaluating learners' skills to engage in activities within a community of practice. This involves real-world practices across multiple dimensions, as outlined below:

- *Experience sharing:* The ability to exchange knowledge and experiences among community members.
- *Engagement and support:* The level of participation in activities and the provision of assistance to community members.
- *Expert involvement:* The integration of expertise to enhance learning and operational activities within the community.
- *Feedback mechanisms:* The ability to provide and receive constructive feedback for skill development.
- *Practices and activities:* The execution of activities that support the development of skills relevant to real-world performance.

b) Design skills assessment

The assessment of design skills focuses on evaluating learners' skills to develop effective educational digital games that promote learning. This is based on key components as follows:

- *Learning design:* The ability to structure and design content aligned with learning objectives.
- *Graphic design:* Skills in creating meaningful and engaging graphics for learners.
- *Storytelling design:* The capability to craft compelling narratives that connect with the learning context.
- *Sound design:* The selection and development of audio elements that enhance the learning experience.
- *Interactive design:* The ability to develop interactive components that foster engagement and stimulate learning for players.

V. Data Analysis

Data collected from learning logs, skills assessments, and interviews will be analyzed using content analysis to gain in-depth insights into the learning process and skill development. Additionally, quantitative data from performance in the community of practice and the assessment of educational digital game design skills will be analyzed by calculating the mean and standard deviation.

The relationship between performance in the community of practice and educational digital game design skills will be examined using correlation analysis. This analysis aims to test the hypothesis that collaboration within an extended reality community of practice influences the development of educational digital game design skills.

VI. Results

A. The Results of Developing a Model for Immersive Digital Learning Experience Design (IDLXD) for Extended Reality Community of Practice to Enhance Educational Digital Game Design Skills

The framework for designing educational digital games is systematically developed through the integration of relevant concepts and skills. The key components include:

1) The conceptual framework

Designing educational digital games requires the integration of concepts, theories, and relevant components in a systematic manner to ensure the developed model is effective and can promote learning efficiently, as shown in the conceptual framework in Fig. 1. The key components include:

Immersive digital learning: Stimulates learners' motivation and sustains engagement by leveraging technology to enhance the sense of presence. This allows learners to express their personality, attitudes, and behaviors within the virtual world to the fullest extent.

Learning experience design: Focuses on creating learning experiences that address learners' needs and interests. It promotes learning by integrating technology into the learning process, ensuring learners gain contemporary and relevant experiences.

Extended reality learning: Delivers realistic and highly interactive learning experiences, enabling learners to gain a deeper understanding of content and better retention. It also increases learners' interest and motivation in the learning process.

Community of practice: Facilitates knowledge sharing and exchange of experiences within an environment that supports collaborative learning and practice.

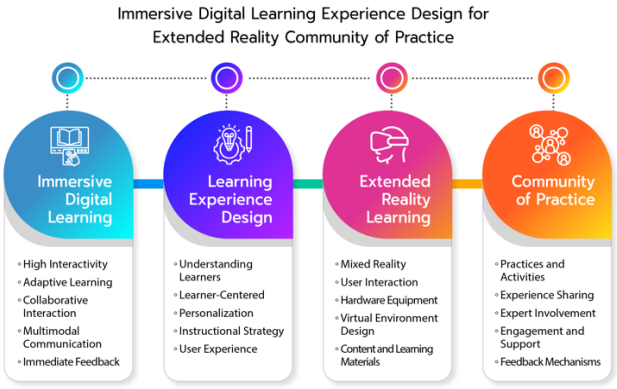

Fig. 1. The conceptual framework of immersive digital learning experience design for extended reality community of practice.

2) The learning process

The learning process designed for the extended reality community of practice aims to support collaborative learning and knowledge exchange among learners, as shown in the learning process in Fig. 2. The developed process includes:

a) Preparation stage

Learners are introduced to foundational lessons on game design concepts and relevant learning theories.

b) Hands-on learning

Practical learning activities emphasize connecting

theoretical understanding with real-world application through active practice.

c) Learning community

Learners share their work and receive feedback from experts and peers within the community.

d) Reflection and iteration

Learners reflect on their own work, receive constructive feedback, and make improvements accordingly.

e) Practical skills assessment

Learners' behaviors are evaluated through activity participation, with a focus on assessing their ability to apply knowledge in practical tasks.

By engaging in these activities, the extended reality community of practice enables members to continuously develop knowledge, skills, and expertise. They foster robust professional networks and promote participatory and sustainable learning.

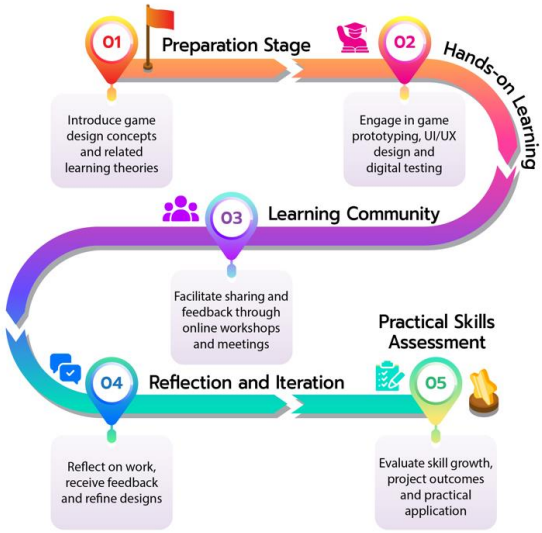

Fig. 2. The learning process for extended reality community of practice.

Fig. 3. Skills developed during engagement in a community of practice.

During participation in a community of practice, learners can integrate various skills to achieve collaborative goals effectively, as shown in community of practice skills in Fig. 3. These include:

1) Teamwork: Emphasizing collaboration and mutual understanding within the community of practice, fostering support and assistance among members to ensure successful outcomes.
2) Problem-solving: Developing creative thinking and strong analytical skills to identify root causes of problems and address them systematically within the community.
3) Communication: Ensuring effective communication by valuing active listening to others' opinions and feedback, which fosters understanding and enhances collaboration.

By embedding these skills, learners can engage with the community of practice in a meaningful way, streamline collaborative processes, enhance overall efficiency, and contribute to the long-term development of knowledge and expertise.

3) The learning outcome

After completing the learning process, learners achieve outcomes aligned with the objectives and measurable results. Educational digital game design is a multifaceted process that integrates diverse skills to create games that serve as both educational tools and engaging learning experiences. This aligns with research in educational digital game design, which emphasizes the integration of instructional strategies, game mechanics, and user experience design to foster meaningful learning [38]. Studies in this field highlight the importance of balancing pedagogical effectiveness and engagement to enhance learners' cognitive, social, and problem-solving skills [40, 41], as shown in educational digital game design skills in Fig. 4. This process includes:

1) Learning design: Establishing clear learning objectives and systematically designing activities that effectively promote learners' understanding and are measurable.
2) Graphic design: Creating efficient visuals that communicate objectives effectively and engage learners. This ensures learners feel connected and can easily comprehend the content.
3) Storytelling design: Crafting compelling narratives that foster learner engagement and motivation, making the learning experience through games meaningful and captivating.
4) Sound design: Enhancing the atmosphere and emotional resonance of the game to reinforce understanding and memory retention of the learning content.
5) Interactive design: Providing learners with engaging and seamless interactive experiences to boost motivation and learning effectiveness.

By integrating these elements, learners are equipped to design educational digital games that combine learning and entertainment and meaningful educational experiences.

Fig. 4. The learning outcome of educational digital game design skills.

Therefore, the importance of designing immersive digital learning experiences for the extended reality community of practice, integrating multiple dimensions to enhance educational digital game design skills, lies in extending traditional learning through innovative experiences. This approach is consistent with research on immersive learning, which emphasizes the importance of engagement, presence,

and experiential interaction in fostering deeper understanding and skill development [20]. By utilizing immersive environments, learners can actively participate in situated learning experiences, improving their ability to apply game design concepts in real-world educational contexts [13, 29]. This approach fosters more effective and enjoyable learning for learners by creating tailored experiences that meet their needs. It also enables collaborative efforts to develop knowledge and skills that can be creatively applied in practice.

Table 2. Results of the evaluation of IDLXD for XR-CoP model

Components of IDLXD for XR-CoP Model	Expert opinion		
	Mean	*S.D.*	Appropriateness
1. Conceptual Framework			
1.1 Immersive Digital Learning	4.40	0.55	High
1.2 Learning Experience Design	4.80	0.45	Highest
1.3 Extended Reality Learning	5.00	0.00	Highest
1.4 Community of Practice	4.60	0.55	Highest
Sum	**4.70**	**0.39**	**Highest**
2. Learning Process			
2.1 Preparation Stage	5.00	0.00	Highest
2.2 Hands-on Learning	4.60	0.55	Highest
2.3 Learning Community	5.00	0.00	Highest
2.4 Reflection and Iteration	4.60	0.55	Highest
2.5 Practical Skills Assessment	4.80	0.45	Highest
Sum	**4.80**	**0.31**	**Highest**
3. Learning Outcomes			
3.1 Learning Design	5.00	0.00	Highest
3.2 Graphic Design	5.00	0.00	Highest
3.3 Storytelling Design	4.60	0.55	Highest
3.4 Sound Design	4.40	0.55	High
3.5 Interactive Design	5.00	0.00	Highest
Sum	**4.80**	**0.22**	**Highest**
Overall	**4.77**	**0.30**	**Highest**

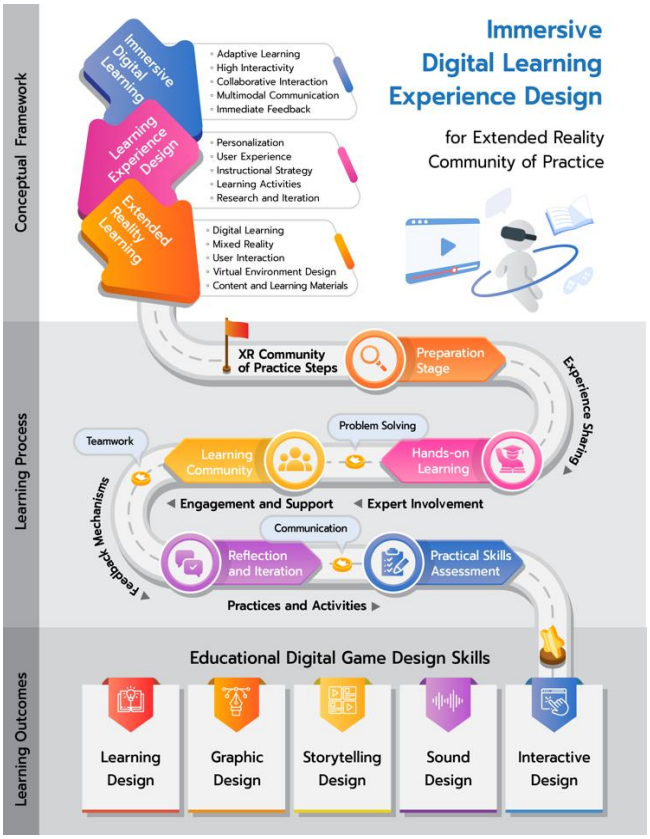

Fig. 5. The model for immersive digital learning experience design for extended reality community of practice to enhance educational digital game design skills.

The analysis results in Table 2 indicate that the evaluation of the immersive digital learning experience design model for extended reality community of practice demonstrates an overall efficiency at the highest level (mean = 4.77, *S.D.* = 0.30). This indicates that the learning model is highly suitable for implementation, as shown in the model in Fig. 5.

However, the experts suggested several improvements, including enhancing the clarity of the implementation process, increasing the model's flexibility to accommodate diverse contexts, and developing supporting tools such as a user manual or a digital platform to facilitate effective implementation. Based on these recommendations, the model was refined to improve its clarity and adaptability for application in various educational contexts.

Therefore, having a conceptual framework that appropriately integrates concepts, theories, and relevant components forms the foundation of all learning processes. This results in a learning process and activities within the extended reality community of practice that enable learners to engage in both experiential and collaborative practices effectively. Moreover, learning outcomes are clearly defined, ensuring that learners achieve measurable results aligned with the intended goals after completing the learning process.

B. The Results of Developing an Extended Reality Community of Practice for Facilitating Immersive Digital Learning Experiences

Creating an extended reality community of practice for immersive digital learning experiences serves as an effective learning medium, engaging learners deeply with content and environments through various digital technologies. These include reality technologies capable of creating digital objects or environments, such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). These technologies integrate to form Extended Reality (XR), seamlessly blending real-world and digital environments. This approach facilitates immersive learning and interactive collaboration, enhancing both individual and collective learning experiences.

The analysis results in Table 3 indicate that the evaluation of the extended reality community of practice, conducted by five experts in virtual reality technology, is presented in Table 3. The evaluation results indicate that the overall quality of XR-CoP is rated as highest in all aspects (mean = 4.70, S.D. = 0.34). These findings suggest that XR-CoP has significant potential and suitability for implementation in immersive digital learning, particularly within the context of extended reality community of practice. Furthermore, it effectively supports the development of educational digital game design skills.

Therefore, the quality of the design focuses on creating engaging and realistic experiences that allow users to deeply immerse themselves while addressing learners' needs for convenience and maximum satisfaction. The content is aligned with learning objectives, enabling learners to develop knowledge and skills effectively. Additionally, it promotes collaborative learning by providing opportunities for exchanging ideas and co-creation. Diverse interactions foster learner engagement, and immediate feedback is provided as instructors guide skill improvement and continually motivate learners toward self-development, as shown in the extended reality community of practice for facilitating immersive digital learning experiences in Fig. 6.

Table 3. Results of the quality evaluation of XR-CoP

XR-CoP	Evaluation Results		
	Mean	*S.D.*	Appropriateness
1. Design Quality			
1.1 Attractiveness and Engagement	5.00	0.00	Highest
1.2 Realism in Immersive Experience	4.20	0.45	High
1.3 User-Centered Design	4.60	0.55	Highest
Sum	**4.60**	**0.33**	**Highest**
2. Content Appropriateness			
2.1 Alignment with Learning Objectives	4.60	0.55	Highest
2.2 Promotion of Collaborative Learning	5.00	0.00	Highest
Sum	**4.80**	**0.27**	**Highest**
3. Learner Engagement			
3.1 Diverse Interactions	4.80	0.45	Highest
3.2 Immediate Feedback	5.00	0.00	Highest
Sum	**4.90**	**0.22**	**Highest**
4. Technology and Usability			
4.1 System Stability and Security	4.40	0.55	High
4.2 User-Friendliness	4.60	0.55	Highest
Sum	**4.50**	**0.55**	Highest
Overall	**4.70**	**0.34**	**Highest**

Fig. 6. The extended reality community of practice for facilitating immersive digital learning experiences.

C. The Results of Enhancing Educational Digital Game Design Skills Among Learners Engaged in Extended Reality Community of Practice

This study focuses on analyzing the enhancement of learners' educational digital game design skills through participation in an extended reality community of practice. The study's findings are categorized into three aspects as follows:

1) Performance evaluation in a community of practice

The analysis results in Table 4 indicate that the learners' performance in the community of practice was rated as highest for activities related to experience sharing and practices and activities. Following this, aspects such as engagement and support, expert involvement, and feedback mechanisms were rated as high. These results demonstrate that learners performed at a satisfactory level within the community of practice, actively participating and engaging in all dimensions effectively.

Table 4. Results of the performance evaluation in a community of practice

Performance Criteria of Community of Practice	Observation Evaluation Results		
	Mean	*S.D.*	Appropriateness
1. Experience Sharing	4.56	0.51	Highest
2. Engagement and Support	4.36	0.64	High
3. Expert Involvement	4.40	0.65	High
4. Feedback Mechanisms	4.48	0.59	High
5. Practices and Activities	4.68	0.48	Highest
Sum	**4.50**	**0.57**	**Highest**

Therefore, the activities within the community of practice highlight the importance of knowledge and experience exchange among members. An environment that fosters engagement and support from both peers and experts stimulates continuous learning. Expert involvement enhances credibility and provides valuable insights that contribute to the development of members' potential. Feedback improve the quality of ongoing development. Additionally, the design of hands-on activities and practices promotes experiential learning and facilitates of acquired knowledge.

Based on the learning logs, learners actively participated in activities on the extended reality community of practice platform, engaging with interactive learning materials and exchanging ideas with peers. This interaction fostered collaborative learning and contributed to the development of digital game design skills, particularly in practices and activities. However, some learners encountered challenges related to engagement and support, as well as limitations in equipment and resources, which may have impacted their learning experience.

2) Assessment of educational digital game design skills

The analysis results in Table 5 indicate that learners' skills in educational digital game design were rated as highest in graphic design, sound design, and interactive design. Following this, learning design and storytelling design were rated as high. These findings demonstrate that learners possess satisfactory skills in educational digital game design, with notable expertise in key areas critical to the development of digital games for learning purposes.

Therefore, educational digital game design skills must encompass multiple areas to create games that serve both as engaging learning tools and enjoyable experiences. Setting clear learning objectives and systematically designing activities facilitates measurable outcomes. User-friendly and meaningful graphic design captures learners' attention effectively. Appropriate storytelling and sound design contribute to an immersive atmosphere and motivate learners. Smooth and meaningful interactivity fosters engagement and enhances learning efficiency.

Interviews revealed that learners found the platform to be highly motivating and useful in improving their understanding of digital game design concepts. Workshops and multiplayer learning sessions were particularly effective in accelerating the learning process and developing their skills. Learners showed increased proficiency in using game design tools like Unity and were able to create game prototypes. There were also suggestions to increase learning

resources, mentorship, and peer learning support in order to improve the learning experience and facilitate the systematic integration of these skills into educational contexts.

Table 5. Results of the assessment of educational digital game design skills

Educational Digital Game Design Skills	Assessment Results		
	Mean	*S.D.*	Appropriateness
1. Learning Design			
1.1 Learner Analysis	4.44	0.51	High
1.2 Learning Objectives	4.32	0.48	High
1.3 Learning Activities	4.40	0.65	High
1.4 Learning Materials	4.60	0.50	Highest
Sum	**4.44**	**0.53**	**High**
2. Graphic Design			
2.1 Color	4.56	0.51	Highest
2.2 Typography	4.48	0.51	High
2.3 Composition	4.68	0.48	Highest
2.4 Accessibility	4.60	0.50	Highest
Sum	**4.58**	**0.50**	**Highest**
3. Storytelling Design			
3.1 Learning goals	4.52	0.51	Highest
3.2 Narrative Structure	4.40	0.50	High
3.3 Player Experience	4.56	0.51	Highest
3.4 Educational Content	4.36	0.70	High
Sum	**4.46**	**0.55**	**High**
4. Sound Design			
4.1 Sound Effects	4.68	0.48	Highest
4.2 Feedback Sounds	4.72	0.46	Highest
4.3 Background Music	4.60	0.50	Highest
4.4 Voice-Over	4.84	0.37	Highest
Sum	**4.71**	**0.45**	**Highest**
5. Interactive Design			
5.1 User-Centered	4.60	0.50	Highest
5.2 User Experience	4.68	0.48	Highest
5.3 User Interface	4.24	0.66	High
Sum	**4.51**	**0.55**	**Highest**
Overall	**4.54**	**0.52**	**Highest**

3) The correlation between community of practice performance and educational digital game design skills

The analysis of relationships using Pearson's correlation coefficient, with statistical results summarized in Table 6.

This study examined the relationship between community of practice performance and educational digital game design skills using Pearson's correlation coefficient. The analysis revealed a very strong positive correlation, with a coefficient of 0.947, which was statistically significant at the 0.001 level ($p < 0.001$). These results highlight that learners who actively participate in a community of practice demonstrate significantly enhanced digital game design skills. Such engagement is associated with the development of critical competencies, including the ability to establish clear learning objectives, craft compelling narratives, and design interactive and innovative user experiences. Moreover, the collaborative nature of community practices facilitated by knowledge sharing, expert feedback, and peer interactions emerges as a critical driver of skill development.

This finding underscores the importance of fostering collaborative learning environments within communities of practice to bridge theoretical knowledge with practical application, ultimately advancing the creative and technical capabilities of learners in educational digital game design. The results contribute to the growing body of evidence supporting the pedagogical value of community-based learning models in achieving substantive skill development outcomes.

Table 6. Correlation between community of practice performance and educational digital game design skills

		Community of Practice Performance	Educational Digital Game Design Skills
Community of Practice Performance	Pearson Correlation	1	0.947**
	Sig. (2-tailed)		<0.001
	n	25	25
Educational Digital Game Design Skills	Pearson Correlation	0.947**	1
	Sig. (2-tailed)	<0.001	
	n	25	25

**. Correlation is significant at the 0.001 level (2-tailed).
Sig. Significance.

VII. Discussion

The development of an immersive digital learning experience design model for an extended reality community of practice highlights a clear trend in creating learning experiences that genuinely connect learners with practical contexts. Specifically, this approach integrates Virtual Reality (VR) and Augmented Reality (AR) technologies with a community of practice in virtual environments to foster active engagement and continuous knowledge exchange [10, 22]. This aligns with research indicating that designing activities and tools in immersive digital contexts with embedded socio-cultural dimensions enhances creativity, problem-solving, and collaborative learning in educational digital game design processes [14–17].

The distinction between this research and other studies is its emphasis on leveraging immersive digital learning environments within Communities of Practice (CoPs) to improve both creative and technical competencies in educational digital game design. While previous research has examined the advantages of community-based learning and digital game design education separately, few studies have looked into how immersive learning experiences within CoPs can effectively integrate theoretical knowledge with hands-on practice to foster skill development.

The study's novelty stems from its pedagogical approach, which combines immersive digital environments, collaborative learning dynamics, and applied creativity in game design education. Unlike traditional instructional methods or generic digital learning approaches, this study emphasizes the synergistic role of immersive CoPs in helping learners translate conceptual understanding into real-world game design skills. The findings shed new light on how immersive digital learning experiences can bridge the gap between theory and practice, highlighting the pedagogical value of CoPs in facilitating substantive skill development.

A. Key Findings from Model Development

The findings demonstrate that integrating an extended reality community of practice with immersive experiences enables learners to practice digital game design skills in simulated scenarios closely resembling real-world educational industry contexts. Digital environments where learners can experiment collaboratively with experts and peers not only enhance systematic prototyping and concept testing but also boost learners' confidence and motivation for

self-improvement. Community-based learning in virtual settings strengthens bonds between learners and experts while fostering intra-group knowledge sharing [10, 11].

Immersive dimensions, such as VR/AR media, allow learners to deeply engage with scenarios, simulations, concept experimentation, and game mechanic development. This learning-by-doing approach aligns with constructivist and experiential learning theories. Immersive media combined with social interactions within a community of practice effectively supports the development of design thinking [22, 25].

B. Quantitative Analysis of Skill Development

Quantitative analysis of data on educational digital game design skills revealed that learners actively participating in an extended reality community of practice showed significantly greater skill development compared to those with lower interaction levels. Data analysis highlighted a positive correlation between collaboration levels in these community and improved creative and critical problem-solving skills in game design. Learners who actively exchanged ideas, shared resources, and provided constructive feedback within the community applied creative design concepts more effectively [36].

The hypothesis that collaboration within the extended reality community of practice impacts the development of educational digital game design skills was supported by statistical data. Specifically, learners demonstrated increased ability to apply design thinking frameworks, develop game structures, enhance player interaction, and evaluate learning experiences. Using knowledge and feedback from the community, learners systematically refined game prototypes, significantly enhancing their design capabilities [38].

Among the various design skills evaluated, sound design received the highest score. This can be attributed to several key factors, including the structured nature of sound design, which allows for clear implementation and refinement based on community feedback, the availability of shared sound assets and collaborative audio design practices within the community, and the relatively lower cognitive load required for modifying and experimenting with sound elements compared to complex game mechanics or visual design. These findings suggest that auditory elements in game design are especially well-suited for iterative learning in an immersive digital environment, highlighting the importance of collaborative sound experimentation in educational game development.

The strong correlation between CoP engagement and skill development in educational digital game design provides compelling evidence that active participation in collaborative learning environments improves technical and creative competencies. This finding emphasizes the importance of fostering inclusive, interactive, and knowledge-rich CoP models to aid in skill acquisition in digital education.

C. Broader Impacts and Challenges

Immersive environments in the extended reality community of practice promote full engagement, leading to the co-creation of knowledge within groups. The potential of integrating social dimensions and immersive technologies to expand learners' analytical, reflective, and practical skills in complex contexts [12]. These findings align with the developed model, which underscores the role of extended reality community of practice in accelerating educational digital game design skill development. This approach could be extended to other learning environments in the future.

Despite positive outcomes, challenges remain, including high costs of technology and digital resources, the need to address basic digital skills gaps among some learners, and the development of qualitative and quantitative assessment tools that accurately reflect game design skill progress. Long-term motivation and effective management of digital learning platforms also require attention.

To address the challenges of incorporating digital games into education in environments with limited technological resources, a multifaceted approach is required. This includes ensuring that low-resource or cloud-based digital games are accessible on simple devices [4]. Including offline modes or hybrid learning approaches can also help learners interact with digital game-based learning when they have limited internet access. Furthermore, combining digital game-based learning with traditional teaching strategies allows learners to engage in interactive learning without overly relying on cutting-edge technology. Furthermore, improving teachers' capacity through training courses allows them to make the best use of the resources at their disposal, ensuring the effective use of digital games in education even when resources are limited [2, 4].

The incorporation of an extended reality community of practice into educational curricula has the potential to improve learning outcomes through immersive experiences and collaborative knowledge sharing. XR allows learners to engage in realistic simulated environments, whereas CoP promotes skill development through interactions with experts and professional networks. Furthermore, this approach makes learning more accessible to a wide range of learners, including those with physical limitations or living in remote areas. However, significant challenges include high costs, technological barriers, and ethical and privacy concerns. Potential solutions include using open-source XR platforms, lowering content development costs, implementing resource-sharing models, improving infrastructure, and enforcing data security policies. Ensuring inclusive design and equitable access will help establish XR and CoP as effective tools for fostering comprehensive and long-term learning experiences.

Virtual reality learning environments must be designed with an eye toward technological obsolescence, which profoundly affects the appeal and efficacy of digital learning tools. The rapid evolution of virtual reality technologies, hardware, software, and supporting platforms makes it imperative to make sure that learning environments remain relevant for new technologies and interesting for users [8, 23]. These environments might become irrelevant without regular updates and fail to offer worthwhile learning opportunities. Maintaining a current design is therefore essential to guarantee that learners keep gaining from excellent, immersive learning opportunities that can be used in fast-changing surroundings [29]. Combining adaptable and flexible design principles, such as platforms enabling automatic updates or industry standards adherence, helps to maintain the efficacy of these learning materials and

guarantees their long-term engagement for users.

D. Challenges in Educational Digital Game Design

Curriculum gaps, a shortage of specialized professionals, and a focus on technical skills rather than holistic learning design are among the challenges that educational digital game developers face. Traditional curricula frequently divide instructional design, game mechanics, and XR technologies, resulting in fragmented learning experiences.

This study introduces the Extended Reality Community of Practice (XR-CoP) to improve learning through iterative design, collaboration, and the integration of storytelling, UX, and pedagogical strategies within XR environments as opposed to traditional programs that focus solely on graphics and programming [26, 27].

This model fills gaps in the digital game design education literature and is consistent with global trends in immersive learning, in which XR improves experiential learning and real-world skill application. It seeks to create a modern, community-driven curriculum for educational game design.

Another important consideration is that educational digital game developers must create games that are accessible to learners of all skill levels. This includes ensuring that the game is compatible with a variety of devices and provides easy access [38]. The content should be simplified to accommodate different learning levels, and the language should be clear and easy to understand. Furthermore, the game should be engaging and appealing by incorporating gamification elements such as reward systems, mission unlocking, and appropriately challenging tasks [44]. Furthermore, the use of supportive technologies such as Augmented Reality (AR) or Artificial Intelligence (AI) can improve personalization and enrich the learning experience. Finally, incorporating the game into the educational curriculum ensures its relevance to real-world learning contexts, making it a valuable tool for developing learners' skills at all levels.

E. Limitations of the Study and Future Work

One of the study's major limitations is the educational constraints in utilizing XR technology, which include the familiarity of both learners and educators with the technology, access to appropriate devices, and infrastructure constraints such as internet speed and the ability of devices to support XR in specific educational institutions. Furthermore, differences in digital skills among learners may influence the learning experience and the efficacy of XR integration in the learning process. Furthermore, the size of the sample group used in this study may affect the findings' applicability to broader educational contexts. Furthermore, because XR technology is still in development, limitations in hardware, software, and investment costs may impede widespread adoption [22, 23].

To address the limitations of using XR in education, it is critical to promote training programs and create learning communities that will improve the skills of educators and learners. Furthermore, using cross-device compatible XR platforms can help reduce hardware constraints. Creating digital literacy preparation courses and learning experiences that adhere to inclusive design principles can help to reduce skill disparities among learners. Increasing sample sizes and conducting mixed-methods research can improve the reliability and applicability of findings. Finally, utilizing open-source XR technologies and implementing a hybrid XR approach can reduce costs while increasing accessibility for broader educational adoption.

IX. Conclusion

This study contributes significantly to the field of immersive digital learning by proposing an Extended Reality Community of Practice (XR-CoP) model as a novel approach to bridging the gap between theoretical knowledge and practical skills in digital game design education. Unlike traditional pedagogical methods, XR-CoP provides an authentic, hands-on learning environment in which learners engage in situated, experiential activities while interacting meaningfully with industry professionals. This combination of immersive learning and professional practice represents a significant shift in the way digital game design skills are developed.

This study's key contribution is the structured framework for implementing XR-CoP in educational institutions. This framework makes recommendations for establishing XR infrastructure, incorporating XR-CoP into curricula, and encouraging industry-academic collaborations to ensure real-world relevance. The study also proposes a novel assessment methodology that prioritizes competency-based evaluation over traditional examination-based approaches, allowing for a more comprehensive measurement of learners' skill growth.

Beyond technical proficiency, this study emphasizes the importance of XR-CoP in developing essential soft skills such as communication, interdisciplinary collaboration, systems thinking, and reflective thinking—all of which are necessary for educational game development. The findings are consistent with emerging global trends in design-oriented learning, highlighting the importance of immersive, community-driven learning environments in promoting holistic educational experiences. This suggests that XR-CoP is applicable not only to digital game design but also to a variety of professional training contexts that necessitate a thorough integration of theory and practice.

Furthermore, this study shows how XR-CoP works as a scalable, adaptive learning model that connects education and industry, ensuring that learners develop problem-solving skills, design expertise aligned with industry standards, and career-ready competencies. The model's potential extends beyond game design, providing a framework for incorporating immersive technologies into a variety of disciplines.

Future research and development should focus on creating XR-based learning experiences that accommodate learners with varying levels of digital skills, as well as improving XR's accessibility and flexibility through the development of education-specific platforms and tools. Furthermore, research should investigate the use of Artificial Intelligence (AI) and learning analytics to personalize content and improve learning experiences for individual learners.

Further studies should investigate the adaptability of XR-based communities of practice in different cultural and educational contexts, ensuring seamless integration into various academic structures. Longitudinal research is required to determine the long-term impact of XR-CoP on

learners' career paths and professional development. Furthermore, efforts should be made to create inclusive XR-CoP frameworks that address diverse learning needs, thereby promoting equitable access to immersive learning opportunities. Finally, ongoing research into the long-term effects of XR on learner behavior and learning outcomes will be critical to ensuring its successful and meaningful implementation in educational settings.

In conclusion, this study demonstrates extended reality community of practice as a transformative mechanism for practice-based, immersive learning that goes far beyond traditional educational models. It lays the groundwork for the future of immersive digital education by demonstrating how extended reality can transform the way we teach, learn, and prepare professionals for rapidly changing, technology-driven industries.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Parwapun Kamtab conducted the research, which involved designing the study, developing a model and an extended reality community of practice to facilitate immersive digital learning experiences, collecting data, performing analysis, and drafting the manuscript. Sawanan Dangprasert contributed by providing expert guidance on research methodology, refining the system's evaluation framework, and reviewing the manuscript for accuracy and coherence. Both authors reviewed and approved the final version of the manuscript.

FUNDING

This research was funded by the Faculty of Technical Education, King Mongkut's University of Technology North Bangkok (KMUTNB), under Contract FTE-2567-11.

ACKNOWLEDGMENT

The authors would like to express their heartfelt gratitude to the Faculty of Technical Education, King Mongkut's University of Technology North Bangkok, for providing the essential resources and unwavering support that made this research possible. Our sincere appreciation goes to the expert evaluators whose invaluable feedback played a pivotal role in refining the immersive digital learning experience design for the extended reality community of practice to enhance educational digital game design skills.

We are equally thankful to the graduate learners who participated in this study for their active collaboration and insightful contributions, which enriched the findings of this research. Lastly, we extend our deepest thanks to our colleagues and mentors for their steadfast encouragement and guidance throughout the research process. Their support and contributions were instrumental in the successful completion of this research.

REFERENCES

[1] Creative Economy Agency (CEA). (August 2021). *Creative Industries Development Report: Software (Games and Animation)*. *Creative Economy Agency (CEA)*. [Online]. Available: https://www.cea.or.th/th/single-industries/Creative-Industries-Development-Report-2021-Software

[2] B. Oberer and A. Erkollar, "Digital games in education: An interdisciplinary view," *Journal of Systemics, Cybernetics and Informatics*, vol. 22, no. 1, pp. 211–230.

[3] S. C. Gurbuz and M. Celik, "Serious games in future skills development: A systematic review of the design approaches," *Computer Applications in Engineering Education*, vol. 30, no. 5, pp. 1591–1612, Aug. 2022.

[4] Z. Yu, M. Gao, and L. Wang, "The effect of educational games on learning outcomes, student motivation, engagement and satisfaction," *Journal of Educational Computing Research*, vol. 59, no. 3, pp. 522–546, Nov. 2020.

[5] S. A. Ishak, U. A. Hasran, and R. Din, "Media education through digital games: A review on design and factors influencing learning performance," *Education Sciences*, vol. 13, no. 2, p. 102, Jan. 2023.

[6] R. Sharma *et al.*, "Guiding teachers' game-based learning: How user experience of a digital curriculum guide impacts teachers' self-efficacy and acceptance of educational games," *Teaching and Teacher Education*, vol. 155, 104915, Mar. 2025.

[7] L.-K. Lee *et al.*, "A systematic review of the design of serious games for innovative learning: Augmented reality, virtual reality, or mixed reality," *Electronics*, vol. 13, no. 5, p. 890, Feb. 2024.

[8] D. Vergara, J. Extremera, M. P. Rubio, and L. P. Dávila, "Meaningful learning through virtual reality learning environments: A case study in materials engineering," *Applied Sciences*, vol. 9, no. 21, p. 4625, Oct. 2019.

[9] G. Baxter and T. Hainey, "Using immersive technologies to enhance the student learning experience," *Interactive Technology and Smart Education*, vol. 21, no. 3, pp. 403–425, Sep. 2023.

[10] J. Hutson, J. Lively, and E. P. Melick, "Learning communities in the metaverse: Integrating high-impact practices and durable skills in a first-year experience course taught entirely in a virtual learning environment," *The International Journal of Learning in Higher Education*, vol. 31, no .1, pp. 97–126, Nov. 2023.

[11] M. Mehdizadeh, M. Pourhaji, and A. Derakhshan, "Evolution of communities of practice, realignment of possible selves, and repositionings in EFL teacher professional identity development: A longitudinal case study," *The Language Learning Journal*, vol. 52, no. 3, pp. 336–348, Jan. 2023.

[12] Digital Learning Institute. (January 2025). What is immersive learning. *Digital Learning Institute*. [Online]. Available: https://www.digitallearninginstitute.com/blog/what-is-immersive-learning

[13] Immersive Factory. (January 2025). Digital learning. *Immersive Factory*. [Online]. Available: https://immersivefactory.com/digital-learning

[14] D. May, I. Jahnke, and S. Moore, "Online laboratories and virtual experimentation in higher education from a sociotechnical-pedagogical design perspective," *Journal of Computing in Higher Education*, vol. 35, no. 2, pp. 203–222, Aug. 2023.

[15] M. Schmidt, Y. Earnshaw, I. Jahnke, and A. A. Tawfik, "Entangled eclecticism: A sociotechnical-pedagogical systems theory approach to learning experience design," *Educational Technology Research and Development*, vol. 72. pp. 1483–1505, Mar. 2024.

[16] M. Pham, K. Singh, and I. Jahnke, "Socio-technical-pedagogical usability of online courses for older adult learners," *Interactive Learning Environments*, vol. 31, no. 5, pp. 2855–2871, Mar. 2021.

[17] I. Jahnke, M. Schmidt, M. Pham, and K. Singh. (January 2020). Sociotechnical-pedagogical usability for designing and evaluating learner experience in technology-enhanced environments. *EdTech Books*. pp. 127–144. [Online]. Available: https://edtechbooks.org/ux/sociotechnical_ pedagogical_usability

[18] J. T. Wong *et al.*, "A learning experience design approach to online professional development for teaching science through the arts: Evaluation of teacher content knowledge, self-efficacy and STEAM perceptions," *Journal of Science Teacher Education*, vol. 34, no. 6, pp. 593–623, Sep. 2022.

[19] A. D. Samala and M. Amanda, "Immersive learning experience design (ILXD): Augmented reality mobile application for placing and interacting with 3D learning objects in engineering education," *International Journal of Interactive Mobile Technologies*, vol. 17, no. 5, pp. 22–35, Mar. 2023.

[20] N. Floor. (January 2025). What is learning experience design? *Learning Experience Design*. [Online]. Available: https://lxd.org/fundamentals-of-learning-experience-design/what-is-learning-experience-design/

[21] ELM Learning. (January 2025). Learning experience design: guide and examples. *ELM Learning*. [Online]. Available: https://elmlearning.com/hub/instructional-design/learning-experience-design/

[22] M. Vasarainen, S. Paavola, and L. Vetoshkina, "A systematic literature review on extended reality: Virtual, augmented and mixed reality in collaborative working life setting," *International Journal of Virtual Reality*, vol. 21, no. 2, pp. 1–28, Oct. 2021.
[23] S. K. Jagatheesaperumal, K. Ahmad, A. Al-Fuqaha, and J. Qadir, "Advancing education through extended reality and internet of everything enabled metaverses: Applications, challenges, and open issues," *IEEE Transactions on Learning Technologies*, vol. 17, pp. 1120–1135, Jan. 2024.
[24] M. Darwish, S. Kamel, and A. Assem, "Extended reality for enhancing spatial ability in architecture design education," *Ain Shams Engineering Journal*, vol. 14, no. 6, 102104, Jan. 2023.
[25] K. Crolla, J. Song, A. Bunica, and A. T. Sheikh, "Integrating extended reality in architectural design studio teaching and reviews: Implementing a participatory action research framework," *Buildings*, vol. 14, no. 6, p. 1865, June 2024.
[26] M. Abir, S. Mursalin, and A. Zaman, "Extended reality in education and training: Enhancing trustworthiness," *International Journal of Science and Research Archive*, vol. 11, no. 1, pp. 1705–1720, Feb. 2024.
[27] V. Kuleto *et al.*, "Extended reality in higher education: A responsible innovation approach for generation Y and generation Z," *Sustainability*, vol. 13, no. 21, 11814, Oct. 2021.
[28] I. Fitrianto and A. Saif, "The role of virtual reality in enhancing experiential learning: A comparative study of traditional and immersive learning environments," *International Journal of Post Axial: Futuristic Teaching and Learning*, vol. 2, no. 2, pp. 97–110, June 2024.
[29] J. Ha, K. Alrayyan, and M. M. L. Alam, "Virtual reality technology for learning detailed design in landscape architecture," *Discover Education*, vol. 3, no. 1, p. 39, April 2024.
[30] A. Dechsling *et al.*, "Implementing virtual reality in special education: Teachers' perspectives," *International Journal of Disability, Development and Education*, vol. 74, no. 10, pp. 1–16, Nov. 2024.
[31] K. Cojorn and K. Sonsupap, "An activity for building teaching potential designed on community of practice cooperated with lesson study," *Journal of Curriculum and Teaching*, vol. 12, no. 4, pp. 62–70, Aug. 2023.
[32] J. P. Walker *et al.*, "Course-based undergraduate research experiences as a Community of Practice (CoP)," *Journal of Chemical Education*, vol. 100, no. 7, pp. 2520–2528, June 2023.
[33] A. Wilson, C. Wilson, and G. Witthaus, "Using a community of practice in higher education: Understanding the demographics of participation and impact on teaching," *International Journal of Teaching and Learning in Higher Education*, vol. 32, no. 1, pp. 39–48, Feb. 2020.
[34] F. Bicchi, "Cultivating communities of practice: From institutions to practices," *Global Studies Quarterly*, vol. 4, no. 1, pp. 1–10, Jan. 2024.
[35] J. Ojasalo, M. Wait, and R. MacLaverty, "Facilitating communities of practice: A case study," *The Qualitative Report*, vol. 28, no. 9, pp. 2792–2813, Sep. 2023.
[36] Y. Li, D. Chen, and X. Deng, "The impact of digital educational games on student's motivation for learning: The mediating effect of learning engagement and the moderating effect of the digital environment," *PLoS ONE*, vol. 19, no. 1, e0294350, Jan. 2024.
[37] Y. Gui *et al.*, "Effectiveness of digital educational game and game design in STEM learning: A meta-analytic review," *International Journal of STEM Education*, vol. 10, no.1, p. 36, May 2023.
[38] H. Pötzsch, T. H. Hansen, and E. L. Hammar, "Digital games as media for teaching and learning: A template for critical evaluation," *Simulation & Gaming*, vol. 54, no. 3, pp. 348–374, Mar. 2023.
[39] J. Westborg. (May 2023). The educational role-playing game design matrix: Mapping design components onto types of education. *International Journal of Role-Playing*. [Online]. (13). pp. 18–30. Available: https://journals.uu.se/IJRP/article/view/306/288
[40] *Educational Game Design*. (March 2019). Game mechanics and learning mechanics. *Educational Game Design.* [Online]. Available: https://educationalgamedesign.com/game-mechanics-and-learning-mechanics.html
[41] S. A. Triantafyllou and T. Sapounidis, "Game-based learning approach and serious games to learn while you play," in *Proc. 2023 IEEE World Engineering Education Conference (EDUNINE)*, 2023, pp. 1–6.
[42] C. Steinkuehler and K. Squire, "Gaming in Educational Contexts," in *Handbook of Educational Psychology,* New York: Routledge, 2023, ch. 4, pp. 674–695.
[43] C. Udeozor, P. Chan, F. Russo Abegão, and J. Glassey, "Game-based assessment framework for virtual reality, augmented reality, and digital game-based learning," *International Journal of Educational Technology in Higher Education*, vol. 20, no. 1, p. 36, June 2023.
[44] S. Dangprasert, "The impact of gamification on creative and innovative skills of graduate students," *Journal of Theoretical and Applied Information Technology*, vol. 101, no. 8, pp. 3077–3087, April 2023.