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Pedagogical Competence Analysis Based on the TPACK Model: Focus on VR-Based Survival Swimming Instructors

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Abstract: This study explores the pedagogical competence of VR-based survival swimming instructors in South Korea, focusing on their application of Technological Pedagogical Content Knowledge (TPACK). Employing qualitative methodology, we conducted in-depth interviews with 11 instructors to understand their instructional strategies within a VR context. The study aimed to identify how instructors integrate TPACK components into their teaching, specifically exploring technological content knowledge (content utilization, equipment preparation, addressing dizziness), pedagogical content knowledge (creating a conducive learning environment, enhancing student engagement), and technological pedagogical knowledge (setting appropriate learning objectives and guidelines, educational assessment), understanding learners, and pedagogical beliefs and philosophy. Our findings reveal that VR-based instructors proficiently blend these knowledge domains to enhance the effectiveness of survival swimming education. The results demonstrate that strategic pedagogical approaches are crucial in leveraging VR technology for educational outcomes, highlighting the importance of instructor competence in successfully implementing VR in teaching. This research contributes to the literature by detailing specific competencies critical for VR-based education and suggesting that a thorough understanding and application of the TPACK framework are essential for optimizing VR's educational potential.

Keywords: survival swimming; virtual reality education; VR-based survival swimming; pedagogical competence; TPACK competence

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1. Introduction

In the contemporary educational landscape, the advent of Virtual Reality (VR) technology has opened new avenues for enhancing teaching and learning processes [1,2]. VR technology, with its immersive and interactive capabilities, presents unique opportunities and challenges in educational settings. It offers the potential to transform traditional learning environments by providing students with experiential, engaging, and personalized learning experiences [3,4]. However, the effective integration of VR into teaching and learning processes requires more than just familiarity with the technology [5]. Teachers must navigate the complexities of choosing appropriate VR content that aligns with curriculum goals, employ pedagogical strategies that leverage VR's capabilities, and address the technical and logistical challenges of implementing VR in the classroom [6].

Virtual reality (VR) technology significantly transforms survival swimming instruction by offering immersive simulations of realistic water safety scenarios within a controlled environment. This innovative teaching method not only improves safety and learning outcomes but also demands that instructors possess comprehensive pedagogical skills tailored to VR's unique requirements. As a pivotal part of physical education, survival swimming equips learners with essential skills for facing life-threatening aquatic situations. However, the effective integration of VR into these programs introduces challenges alongside opportunities, necessitating instructors to adeptly navigate the blend of technology and pedagogy to maximize the educational benefits of VR while addressing its implementation complexities.

Against this backdrop, the Technological Pedagogical Content Knowledge (TPACK) framework provides a robust model for analyzing and understanding the competencies that are crucial for educators in technology-rich environments [7,8]. This model underscores the necessity for educators to possess a synergistic understanding of the interplay between technology, pedagogy, and content knowledge to maximize the educational potential of VR [9,10].

This research article aims to explore the pedagogical competence of swimming instructors within the TPACK framework, offering insights into the intersection of technology, pedagogy, and content knowledge in the context of VR-enhanced survival swimming instruction. By delving into the pedagogical competence of VR-based survival swimming instructors through the TPACK framework, this article contributes to the expanding field of technology-enhanced learning. It aims to enhance our understanding of the pedagogical dynamics at play in VR-enhanced education and inform the development of training programs that can better prepare instructors for the challenges and opportunities presented by VR technology in survival swimming instruction.

2. Theoretical Background

2.1. VR Technology and TPACK

Virtual reality (VR) in education draws significantly from John Dewey's experiential learning theory, emphasizing the critical role of direct experiences in effective learning [11]. Dewey's critique of traditional education for its reliance on adult standards highlights the need for educational content that resonates with the learner's experiences [12]. VR technology, by facilitating immersive experiences, blurs the line between direct and indirect experiences, thereby expanding the scope of experiential learning in modern educational contexts. This immersive technology enables learners to engage with educational content actively, making the learning process more meaningful and closely aligned with their experiential range [13].

The advancement of VR technology has introduced a new dimension to educational experiences, offering near-realistic simulations that mimic direct interactions with the environment [14]. These technologies enhance the sense of presence, or the feeling of being "there" in a virtual environment, which is pivotal for immersive learning [15]. This heightened sense of presence, achieved through interactive and vivid simulations, contributes to a more engaging and impactful learning experience. It suggests that VR can effectively bridge the gap between theoretical knowledge and practical application, making abstract concepts more concrete and understandable for learners.

Design considerations for VR-based educational simulations highlight the importance of realism, relevance, and interactivity in creating effective learning experiences [16]. By mirroring real-world scenarios and fostering active learner participation, VR simulations can offer meaningful educational experiences that transcend traditional learning boundaries. The educational utilization of VR not only addresses the limitations of passive learning but also opens new possibilities for active engagement and experiential learning [17]. As VR technology continues to evolve, its integration into educational practices promises to revolutionize how learners interact with knowledge, making learning a more dynamic, immersive, and personally relevant process [18,19].

Jing, Wang, and Zhang [20] found that VR game teaching significantly enhances immersion among college students, fostering a more intuitive and clear understanding of professional knowledge, which boosts learner enthusiasm and interest. This supports the view that VR facilitates immersive learning experiences that are highly effective. Additionally, Makransky and Lilleholt [19] observed that immersive VR significantly enhances emotional processes and perceived learning outcomes by increasing scores in presence and motivation compared to desktop VR, thus creating a more engaging and emotionally impactful learning environment. Similarly, Chavez and Bayona [21] highlighted the crucial roles of interaction and immersion in VR, noting its ability to simulate experiences that closely mimic reality, which supports effective learning.

Dhimolea, Kaplan-Rakowski, and Lin [22], in their systematic review on high-immersion VR for language learning, found that VR's immersive environments are particularly beneficial for vocabulary acquisition, corroborated by positive learner feedback. Furthermore, Chen and Hsu [23] explored the impact of self-regulated, mobile game-based English learning within a VR environment, demonstrating that elements like immersion, flow, and presence significantly enhance self-efficacy and self-regulation, which are essential for effective learning. These studies collectively underscore the profound impact of immersive VR environments on enhancing various aspects of the educational experience, reinforcing VR's potential as a transformative tool in education.

The TPACK model builds upon Shulman's framework (see Figure 1), outlining three essential competencies for educators: Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK)—an amalgamation of knowledge concerning what to teach and how to teach it [24].

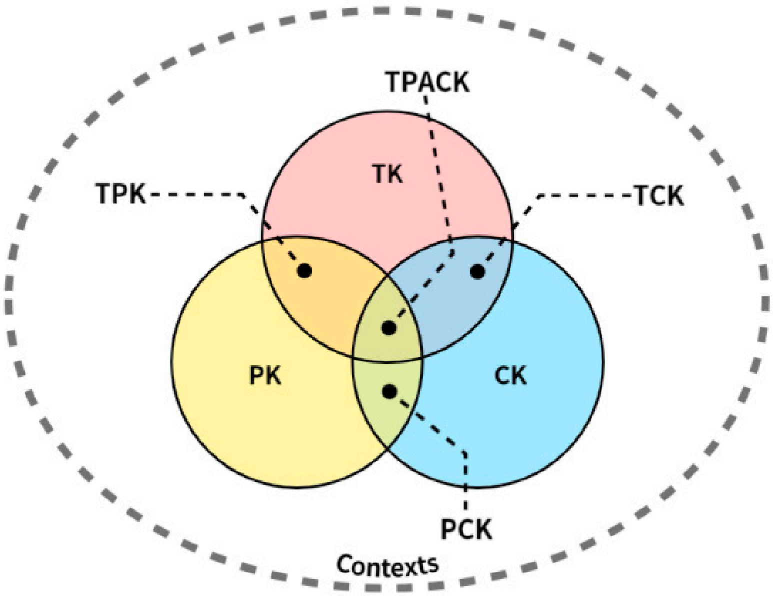


Figure 1. Conceptual diagram of Shulman's TPACK.

The TPACK framework, initially proposed by Mishra and Koehler [25], represents a comprehensive model for understanding the requisite knowledge teachers need to effectively integrate technology into their teaching practices. The framework delineates the complex interrelationships among three primary forms of knowledge: CK, PK, and Technological Knowledge (TK). Central to the TPACK framework is the intersection of these knowledge domains, emphasizing that the effective integration of technology in teaching requires a synergistic understanding of how technology influences pedagogical strategies and content delivery [7,26–28].

Additionally, Angeli and Valanides [29] argued that TPACK should consider aspects beyond content knowledge, pedagogical knowledge, and technology knowledge. They introduced the concept of ICT-TPACK, which extended TPACK by including teachers' educational beliefs and philosophies. This extension provides a comprehensive framework for understanding how teachers approach technology and expand their understanding of students' learning.

The advent of VR technology in educational settings introduces new dimensions to the TPACK framework. Voogt et al. [30] argue that VR technologies necessitate an expansion of the traditional TPACK model to accommodate the unique affordances and constraints of immersive learning environments. VR's capability to simulate realistic scenarios provides an innovative platform for experiential learning, especially in disciplines requiring hands-on experience, such as survival swimming instruction [31].

Analyzing pedagogical competencies within the TPACK framework for VR-based instruction involves examining how instructors leverage VR to enhance learning outcomes. Huang et al. [32] emphasize the importance of instructors' TK in selecting and utilizing appropriate VR tools and applications that align with educational objectives. Furthermore, PK is critical for designing instructional strategies that exploit VR's immersive nature to foster engagement and facilitate learning [33–37].

In the context of survival swimming instruction, VR technology offers unique opportunities to simulate water safety scenarios, providing learners with risk-free environments to practice and develop essential skills [38]. The application of the TPACK framework in this domain requires instructors to possess deep CK of survival swimming techniques, coupled with an understanding of how to effectively convey this content through VR-based pedagogical methods.

Despite the potential benefits of VR in education, implementing VR-based instructional strategies poses challenges. Instructors must navigate technological barriers, develop new pedagogical approaches, and adapt content to suit the immersive VR environment [39]. However, these challenges also present opportunities for innovation in teaching and learning practices. By developing competencies across TPACK domains, instructors can create engaging and effective VR-enhanced learning experiences that cater to diverse learner needs and preferences [40].

The literature on the TPACK framework in the context of VR-based education underscores the importance of a holistic approach to integrating technology into teaching practices [1,5,10]. This entails a balanced amalgamation of CK, PK, and TK, tailored to the affordances of VR technology. As VR continues to gain traction in educational settings, further research is needed to explore the development of TPACK competencies specific to VR-enhanced instruction, with a view to optimizing the educational potential of this transformative technology.

2.2. Survival Swimming Education and VR Technology

The 2014 Sewol ferry disaster, which led to the loss of 304 lives out of 476 passengers, mostly students, significantly highlighted the critical need for enhanced survival swimming education in South Korea. This tragedy prompted a nationwide re-evaluation of water safety protocols and spurred the South Korean government to implement rigorous measures to bolster national and individual safety. Key among these measures was the integration of survival swimming education into the school curriculum as a vital part of "water activity safety", aimed at preventing future maritime disasters.

In a further response to strengthen water safety, the educational curriculum was revised to include not only practical swimming but also specialized survival swimming education and emergency escape training. By 2016, it became compulsory for education college entrants to have swimming as a mandatory subject, ensuring that future educators are well-prepared to teach water safety effectively. The Ministry of Education developed specific plans to expand practical swimming and water safety training through its physical education key tasks plan, setting a target of 10 h of related education for elementary and middle school students, which includes a significant component of 2 h dedicated to survival swimming to comprehensively enhance students' water safety skills. The standard survival swimming curriculum by stages is in Table 1 [41].

Therefore, all students in South Korea must take this course. VR-based survival swimming courses were adopted and spread by more schools when COVID-19 reached its peak. The content of virtual reality-based survival swimming education was designed based on actual students' survival swimming practices. Virtual reality in survival swimming education significantly enhances learners' ability to recognize and respond to water-related hazards in a realistic virtual setting, actively promoting water safety and preventive awareness among learners [42].

Table 1. Elementary school survival swimming education standard curriculum.

Stage	Goals	Details
Adapting to Water	Becoming Friends with Water	Activities include getting wet, learning entry methods, walking and running in water, and holding breath underwater.
Breathing	Breathing Techniques	Activities for learning breathing methods underwater, including blowing air out through the nose and breathing exercises while holding onto the wall.
Floating for Survival	Floating in Water	Activities for learning various floating methods, including using equipment for survival floating and floating without equipment.
Diving	Diving	Activities include touching the bottom of the pool and turning underwater.
Maintaining Body Temperature	Body Temperature Maintenance Methods	Activities for learning various methods to maintain body temperature underwater, including wearing life jackets and activities for individual and group body temperature maintenance.
Moving	Moving	Activities for learning how to move in water, including moving with a life jacket and passing obstacles underwater.
Evaluating	Evaluating	Reviewing and evaluating the learned content.

The VR software teaching content was developed by the company that received approval for safety education from the Office of Education in the Korean government to provide survival swimming lessons. This means that VR-based survival class instructors in Korea teach based on standardized teaching content approved by the government, and all students taking survival class courses complete a standardized course. Therefore, if adjustments are necessary, they can be made within the scope approved by the Office of Education.

The VR device used in this study is a motion-sensing device with two touch controllers. The educational VR software used is the commercially available VR Survival Swimming developed in March 2022. These components are shown in Figure 2, and detailed information is provided in Table 2.

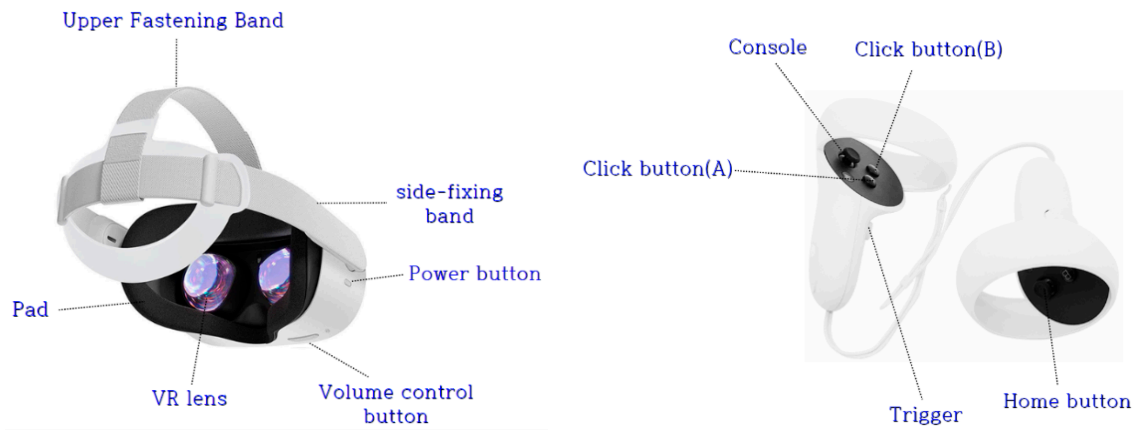
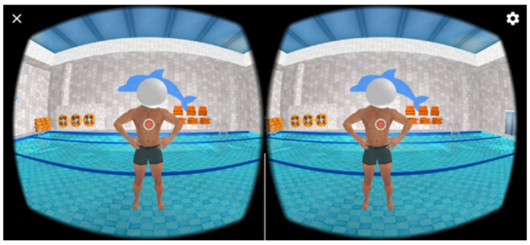
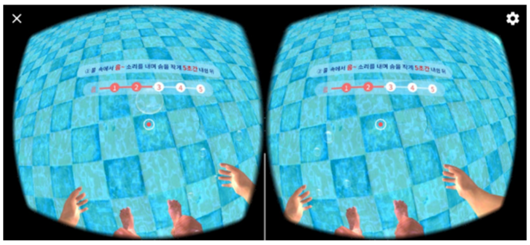
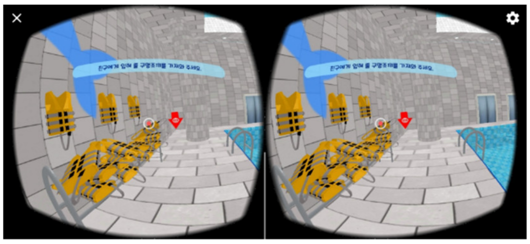
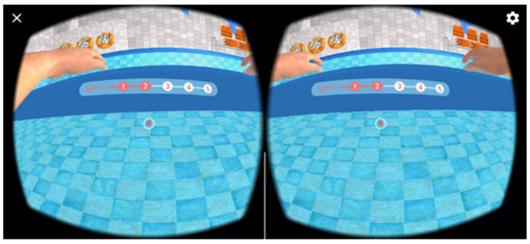
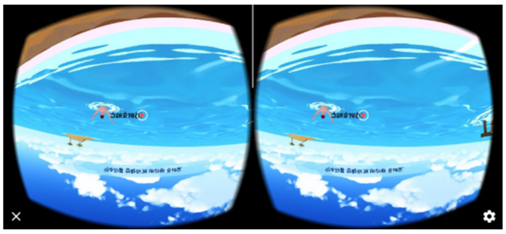
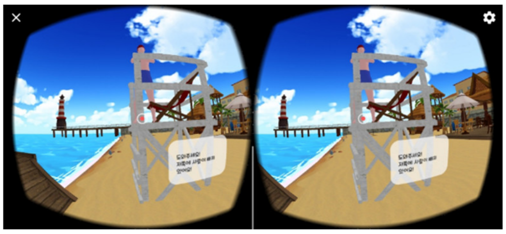


Figure 2. VR headset components and touch controller.

In the context of this study, pedagogical competence centers on the swimming instructors' ability to facilitate an environment where students actively engage in VR-based survival swimming education using VR devices. This involves guiding students to manipulate VR content, step-by-step survival, learning to swim, and perceiving objective success experiences. Proficiency in applying VR content aligned with survival swimming is a crucial aspect of the pedagogical competence required for such instruction.

Table 2. Survival swimming curriculum in VR content.

	
Preparing for Swimming: Learning the Characteristics of Water Through an Understanding of Gravity and Buoyancy.	Floating Survival: Learning How to Float in Water with Minimal Energy Consumption.
	
Getting Acquainted with Life Jackets: Learning How to Wear Life Jackets Through VR.	Moving by Holding a Kickboard: Acquiring the Skill of Moving Using a Kickboard Through VR.
	
Diving: Learning Diving Techniques Through VR.	Rescuing Using Various Objects: Acquiring Various Rescue Methods Through VR.

3. Research Methodology

3.1. Research Participants

In qualitative research, when sampling, it is necessary to consider two principles: appropriateness and sufficiency. "Appropriateness" refers to selecting suitable participants who can provide vivid and rich descriptions of the phenomenon being explored, and "sufficiency" means that data collection must be rich enough to adequately explain the research phenomenon [43,44].

Accordingly, in this study, the criteria for selecting research participants to deeply explore and describe the instructional competencies of VR-based survival swimming instructors are described as follows. First, the target participants are professionals who have recently taught survival swimming to students at elementary schools in different regions and can be considered "swimming specialist instructors", capable of smooth communication for conducting interviews. Second, those who fully understand the purpose of this study and voluntarily agree to participate in the research were targeted.

To select individuals who can share vivid and rich experiences (information-rich case), with the help of managers at VR-based survival swimming education institutions, snowball sampling, a method of purposeful sampling where participants introduce other participants, was used [45].

The purpose of the research, data collection methods, and selection criteria were explained to participants over the phone. We also provided a brief description of the study. From September to October 2022, 18 research participants were recruited over seven rounds. The researchers confirmed the suitability of the selection criteria through direct phone communication. Three instructors could not be reached by phone, and five declined to participate in the interviews. Finally, 11 participants, including one additional participant introduced by a selected participant, attended the in-depth interviews. The participants' personal characteristics and information are provided in Table 3.

Table 3. Personal characteristics and information of research participants.

Participants	Gender	Experience	Characteristics
instructor A	female	3 years 2 months	After retiring as a synchronized swimming athlete, worked as a swimming and water survival instructor at a swimming pool.
instructor B	male	3 years 4 months	Holds a Water Survival Instructor certification and plans VR water survival content.
instructor C	male	3 years 2 months	A major in Physical Education, developed a VR water survival instructional plan.
instructor D	female	8 years 2 months	After retiring as a synchronized swimming athlete, worked as a swimming and water survival instructor at a swimming pool.
instructor E	male	3 years 4 months	Developed a VR-based water survival instructional plan and conducted VR-based outreach water survival education primarily for schools.
instructor F	female	3 years 3 months	Planned VR-based water survival content and conducted VR-based outreach water survival education primarily for schools.
instructor G	female	6 years 3 months	Started a career in water safety in their early 20s, beginning as a lifeguard.
instructor H	male	4 years 8 months	Holds a Water Survival Instructor certification and plans VR water survival content.
instructor I	male	4 years 7 months	Developed a VR-based water survival instructional plan and conducted VR-based outreach water survival education primarily for schools.
instructor J	female	8 years 3 months	Based on their experience as a swimmer during school days, they instruct swimming and water survival to students.
instructor K	male	5 years	Planned VR-based survival swimming content and conducted mobile VR-based survival swimming education primarily for schools.

3.2. Data Collection

Data were collected through in-depth interviews with research participants from September to November 2022. The interviews were conducted at times and places chosen by the participants to ensure a comfortable environment for them to freely express their experiences regarding VR-based survival swimming instructions. On average, two interviews were conducted, with each interview lasting from a minimum of one hour to a maximum of approximately four hours. The average interview duration was approximately 1 h and 40 min. Interviews were conducted until data saturation was reached.

During the first interview, we explained the research purpose and methods, informed participants that the interviews would be recorded, and obtained their consent for participation. Interviews began with general questions regarding the participants' backgrounds. These initial questions provided a context for their subsequent responses and made the data more accessible for analysis [46].

The interview questions were organized into sub-areas that articulate the core themes of the study, structuring the questions presented within the in-depth interview framework. These sub-areas are essential as they cater to the diversity of question types and backgrounds, ensuring each is strategically aligned with eliciting specific research outcomes [47]. The questions posed during the interview included the following: "Are you familiar with operating VR devices and managing technical errors?", "What teaching strategies do you employ to ensure a smooth class?", "How do you address disruptions caused by students during class?", "How do you describe the VR experience to your students?", "How do you assess student performance in the VR experience?", "Do you implement any strategies to enhance student engagement during class?", "As an instructor, do you adhere to any specific beliefs or philosophies?".

During the interviews, participants were encouraged to share their experiences with technology, pedagogy, and content knowledge in VR-based survival swimming instruction. This was facilitated using floating prompts, where key terms significant to the participant's narrative were reintroduced in the form of questions, alongside strategic interjections to stimulate deeper sharing. Example questions were "Would you please describe in more detail what you said?", "What else comes to mind?", and "How does it come to mind?" These techniques helped maintain the natural flow of conversation and ensured active participation [46].

To safeguard against potential disruptions in the dialogue, additional questions were prepared in advance. Moreover, careful observation of the participants' expressions, attitudes, avoidance of topics, non-verbal behaviors, and the usage of key terms were crucial for organizing and analyzing the data effectively. Rather than summarizing or excerpting, the researcher's detailed notes and verbatim records of the interviews were employed to maximize the accuracy of the data collected.

3.3. Data Analysis

Qualitative data analysis involves organizing and assigning meaning to the collected data. Qualitative research aims to derive themes and meanings from data and involves reducing the data while identifying and associating analytical categories [48]. In this study, data collected through in-depth interviews were analyzed using inductive analysis [45], a qualitative research method.

In the process of transcribing interviews into text for data analysis, we obtained consent from the research participants to record all in-depth interviews to prevent data loss. After the planned interviews, we began analyzing research-related data and recorded content directly related to the research topic.

First, the text was separated into meaningful statements by repeatedly reading the recorded content. We used a detailed approach to examine paragraphs, sentences, and words to extract overall themes and meanings from the data.

We used a segmentation method to derive the meaning of the statements made by participants. We conducted noun frequency analysis using the Voyant Tool. The Voyant Tool was used to extract words, combine similar words, refine them primarily based on core words, and visualize them. When the analyzed text is uploaded to Voyant Tools (voyant-tools.org accessed on 2 August 2023), it allows various vocabulary-based analyses and visualizations. Unlike text-mining methods that use computer languages such as R or Python, Voyant Tool offers immediate visual analysis results without running complex programming languages [49]. After extracting the keywords, we conducted part-of-speech tagging to select the most suitable morpheme analysis result for each word while considering the context.

4. Research Findings

The results of the analysis of the interview contents are as follows:

4.1. TCK (Technological Content Knowledge)

TCK, representing teachers' knowledge of using technology for specific subjects, plays a crucial role in VR-based survival swimming education. Instructors highlighted its significance in the following areas.

4.1.1. Content Utilization

Instructor B effectively used VR to enhance survival swimming classes, emphasizing the need for TCK in content development and education.

Diversifying students' learning experiences and providing various methods to achieve learning objectives was also mentioned as a focal point.

> *In the surviving swimming classes, students first used VR devices to actively engage in experiential content. As the class involves physical movement, most students remain focused on maintaining a positive class atmosphere. After using the experiential content, we utilized lower dizziness viewing content and provided students with a view of teaching in a real swimming pool.* (Instructor B)

Interpreting Instructor B's interview from the TCK perspective of the TPACK theory underscores the importance of TCK in developing and using VR content.

Instructor G explained that the VR survival swimming content he used was designed to help learners achieve their learning goals. This implies the need for TCK when developing VR content to ensure that learners reach their learning objectives.

Additionally, Instructor G emphasized that the VR content simulates potentially life-threatening situations during water play. The use of technological content knowledge motivates learners by providing them with internally driven motivation and aids them in achieving their learning goals.

Furthermore, Instructor G considered VR content to be an effective educational resource that can trigger both intrinsic and extrinsic motivation in learners. This demonstrates the importance of technological content knowledge in stimulating curiosity and motivation among learners using VR technology.

> *The VR content I use in my classes is designed to naturally help students reach their learning objectives. For example, it mainly consists of content in which students must figure out how to deal with potentially life-threatening obstacles in water-play situations. These contents instill an "I'm definitely going to tackle this dangerous situation" mentality in learners, promoting intrinsic motivation and helping them achieve their learning objectives. VR content is an excellent resource for triggering both intrinsic and extrinsic motivation. I think it is part of an instructor's role to provide content suitable for the situation using the necessary technological content knowledge.* (Instructor G)

4.1.2. Equipment Preparation

Instructors must choose and utilize technology flexibly and appropriately based on the learning context and teaching content, including the learners and instructional methods [50].

Interpreting Instructor B's interview content from the TCK perspective of the TPACK theory emphasizes its crucial role in effectively managing VR devices and applying them appropriately to the classroom.

Instructor B recognized the importance of managing VR devices, ensuring each student had one, and preparing spare equipment for potential issues. This ensures active student participation in the class and demonstrates the need for TK for equipment management and maintenance, respectively.

In actual classes, the use of CPR manikins for lifesaving training is illustrated, emphasizing the importance of knowing how to use these devices based on technological content knowledge. Additionally, as the number of students increases, it is important to ensure that sufficient equipment is available to provide each student with opportunities for practical training.

Finally, Instructor B mentioned the need to check VR devices or experiences to prevent interruptions during lessons. This implies the importance of having procedures and knowledge based on technological content to anticipate and resolve potential issues that may occur during lessons.

> *As a rule, we prepared enough VR devices for each student to use individually, and also had a spare amount for cases of device damage and malfunction, ensuring student participation in class. For CPR lessons in the higher grades, we had three units of CPR manikins per class. If there were more than 30 students, additional equipment was provided to ensure that each student had sufficient opportunities for practice. Additional*

equipment was prepared for consecutive lessons in which equipment malfunctions were more likely to occur. We also need to check VR devices or experience in advance to prevent interruptions in lessons. (Instructor B)

Interpreting Instructor C's interview content from the TCK perspective of the TPACK theory underscores its importance for the effective use of VR equipment and its impact.

Instructor C mentioned critical equipment such as VR devices and CPR manikins, emphasizing their central role in the class. Therefore, he highlighted the significance of routinely inspecting this equipment both before and after lessons.

In particular, Instructor C was concerned about the occurrence of dizziness among students, owing to the prolonged use of VR equipment. To address this issue and enhance their comfort and learning experiences, they provided alternatives to VR equipment. This perspective aligns with the use of TCK to consider students' diverse learning capabilities and styles.

Instructor C helped students who experienced dizziness with VR devices by offering them non-VR materials or 2D versions of VR content. In this way, students could select the learning path that suits them best, which is consistent with TCK's view of considering learner diversity and individualizing learning content.

Because they are essential equipment needed for the class, it is really important to check the equipment before and after each lesson. For example, if there is a problem with the VR device, students won't be able to see the VR survival swimming content, which is central to the lesson, thus breaking down the overall objectives of the class. Furthermore, if there is an issue with the CPR manikin, it reduces the effectiveness of the students' practice of CPR and also increases the risk of injury, so it's absolutely necessary to check the equipment. (Instructor C)

4.1.3. Addressing Dizziness

VR content has the advantage of directly immersing participants in a realistic experience. However, VR-induced dizziness is a common challenge.

According to Kwak et al. [51], the causes of VR-induced dizziness originate from hardware such as VR headsets or VR software, and solutions should be addressed in both areas.

Instructor E mentioned that many students were curious about using the VR equipment during class. However, some students may experience dizziness with prolonged use. To enhance students' comfort and learning experiences, Instructor E provided an alternative approach to using VR equipment. This highlights the use of TCK to accommodate students' diverse abilities and learning styles. This enabled students to choose the most suitable learning path and aligns with the perspective of TCK, which considers learner diversity and individualizes learning content.

In VR device-based lessons, many students start with curiosity, but after extended use, some students occasionally experience dizziness, making it difficult for them. I provided alternative materials for these students. I prepare content that allows students to learn about real-life survival swimming or create 2D versions of VR content that can be viewed on a classroom screen. To ensure that students with a lower tolerance for the VR experience understand the content well, explanations are necessary. I think that preventing students' dizziness is an important skill that can improve lesson quality. (Instructor E)

The findings from interviews with instructors emphasize the critical role of TCK in the successful integration of VR technology into survival swimming education. The instructors highlighted the importance of technological content knowledge for effectively utilizing VR devices, managing equipment, and addressing challenges such as VR-induced dizziness. They also emphasized the need to provide alternative materials to accommodate students with different learning needs and preferences.

4.2. PCK (Pedagogical Content Knowledge)

Pedagogical content knowledge (PCK), focusing on pedagogical methods for specific content, is essential for VR-based survival swimming classes.

4.2.1. Creating a Learning Environment

When using virtual simulations, it is possible to enhance student engagement and create a sense of presence in the classroom [52]. However, even if various technological learning environments are available, their effectiveness depends on the teachers' pedagogical knowledge [53]. If technology is not seamlessly integrated into the teaching and learning design, it may merely be seen as a "novelty" or "gimmick", leading to less-than-expected results [54]. In the context of VR and simulator-based survival swimming classes, such novelty can disrupt the normal class atmosphere.

Instructor E's interview underlined the importance of pedagogical content knowledge for delivering educational content effectively and managing the learning environment to encourage student participation.

Instructor E mentioned that some students engage in disruptive behavior during class, which can compromise the learning atmosphere. In such situations, Instructor E explained that they make efforts to maintain classroom discipline and the right atmosphere, showcasing the role of PCK in managing the learning environment.

Furthermore, Instructor E noted that when the class atmosphere becomes chaotic, it affects not only the students at the front but also those at the back. To lead the class atmosphere in the desired direction, they emphasized the importance of effective class management. This highlights the significance of PCK in effectively delivering content and encouraging student participation.

4.2.2. Enhancing Student Engagement

Students are more likely to participate actively in class when their intrinsic motivation is stimulated. However, intrinsic motivation has limitations in terms of students generating it themselves. This becomes evident when the right conditions are created and the learner's latent motivation manifests externally, aligning with their level and interest [55].

Instructor H emphasized the importance of creating an atmosphere in a virtual space that is similar to reality. This falls within the realm of PCK in terms of adjusting the context of educational content to effectively convey it and keep students focused.

Instructor H also mentioned the use of recreational and fun elements. Such an approach is a PCK strategy that captures students' attention and makes the class more engaging.

When students struggle to concentrate, Instructor H mentioned using voice commands and control to maintain their attention, which is one of the strategies within PCK to effectively manage content and encourage student participation.

Finally, when students encounter specific difficulties during class, Instructor H uses positive reinforcement and praise to motivate them. Using PCK boosted students' confidence and sustained their motivation.

> *In a virtual space, even though it's a virtual space, you need to create an atmosphere that feels like reality. However, if that does not work, I use many recreational and fun elements. Clap three times, or follow the teacher and focus. Children can use words to concentrate on creating noise. For example, "Clap three times!" or "Follow the teacher, focus!" It can be like that. If this method does not work, I ask, "Is your voice too soft? Would you like to have more fun during this VR experience?" Children start to follow more diligently because they think, "Is this all I can do?" I praised the students who were completely uncontrollable. By praising them first and continuing with the lesson, they worked hard not to disappoint and focused well. Injecting fun elements at certain intervals to help students concentrate is helpful for class management.* (Instructor H)

Instructor F uses an approach to predict the content and situation of the class and to create and use appropriate PPT materials. This is a crucial aspect of PCK, as it helps to effectively convey educational content and facilitate students' understanding.

Furthermore, Instructor F actively employed questions to interact with students, encouraging them to express their thoughts and comprehension and helping them review and understand the content, making it a key tool within PCK.

> *Based on the content and situations that students find less engaging, I prepare PPT materials in advance and use them during the class. In addition, I made an effort to interact with students by asking many questions. It allows students to maintain concentration during class and accurately grasp the class's objectives.* (Instructor F)

At the beginning of the class, Instructor A requested cooperation from the students and simultaneously mentioned the VR content that would make the class enjoyable. This approach is a part of PCK, demonstrating how the instructor combines educational content with the learning environment.

> *Instructor A motivated students to stay focused in class. This is a crucial aspect of PCK—providing a method to deliver educational content while keeping students' attention and stimulating their interests. "At the start, I tell the kids that if they cooperate with me in class, they'll get to experience fun VR content. This motivated them to concentrate in class".* (Instructor A)

4.3. TPK (Technological Pedagogical Knowledge)

TPK plays a crucial role in teachers' ability to use technology to enhance learning and tailor it to students' levels and needs within the classroom. This means that teachers have the knowledge and skills necessary to effectively leverage educational technology to optimize students' learning experiences.

4.3.1. Setting Appropriate Learning Objectives and Guidelines

According to goal-setting theory in education, well-defined and cognitively established goals are fundamental to motivating self-regulation. These goals not only induce motivation but also continually enable students to monitor their progress towards them, ultimately driving them to achieve their objectives [56–58]. Furthermore, clear goal-setting motivates students to develop effective learning strategies and directly regulate their activities [59].

Instructor C emphasized the importance of providing clear learning objectives and exploration guidelines for each session and tailoring VR experiences to these objectives to enhance student understanding. This encourages active participation and allows students to feel a sense of accomplishment and satisfaction once they meet their learning objectives.

Additionally, the instructor confirmed whether students had achieved the objectives during the session, thus increasing their achievement and satisfaction. This approach utilizes TPK's core concept of pedagogical technology to create a learning environment that enhances students' understanding and engagement.

> *Even in survival swimming, learning objectives and exploration guidelines differ from one session to the next, and providing these guidelines significantly affects students' understanding, academic achievement, and overall satisfaction. When students know what they are learning in each lesson and what goals they need to achieve, they can participate more actively in class. Moreover, they gained a sense of accomplishment and satisfaction when they achieved these goals. For instance, in the first session, "Getting Acquainted with Water", the goal was to eliminate fear of water and make students feel comfortable with it. If we introduce content related to diving right from the start, it may confuse students about their learning objectives. Therefore, we consistently provided clear learning objectives and exploration guidelines, delivered appropriate VR experiences, and confirmed the achievement of these goals at the end of each session.* (Instructor C)

Instructor K highlighted the importance of explaining to students the consequences of incorrectly performing chest compressions before embarking on full-scale CPR training.

This practice falls under the category of effective utilization of digital technology in education. VR simulators enable students to experience the consequences of incorrect techniques in safe and controlled environments. This helps students acquire safe and effective lifesaving skills for real-world applications. This approach combines the instructor's digital skills with educational knowledge, playing a pivotal role in providing practical education. The key function of such educators is to effectively utilize digital technology to enhance their learning experience and ensure that students acquire safe and useful skills.

> *Before students engage in full-scale CPR training, it is important to explain what occurs when incorrect chest compressions are performed. The advantage of a simulator is that it can clearly indicate when a technique is incorrect. The condition of the subject appeared on the screen. In this way, students can learn. In this manner, one can also confirm whether the students at the back have understood. Moreover, it becomes easier for the person performing the compressions to keep track of the correct technique. This could be accomplished by combining digital technology with education.* (Instructor K)

4.3.2. Educational Assessment

Given the individualized nature of VR-based survival swimming lessons, in which each student is independently engaged with a personal device, the process of educational assessment is crucial. All participants adopted the common approach of using a simple quiz to assess students after their VR experience and CPR simulator activities. As the classes mainly focused on experiential learning, time was allocated at the end of the session for students to review the content covered during the lesson.

Instructor D employed VR experiences to engage students in the lesson and followed them with quizzes to hold their attention and focus. This method uses digital technology to make learning interesting and beneficial. The quizzes were designed to be simple because students had limited prior experience with swimming survival. This approach allowed for easy comprehension and recall of the material. At the end of the lesson, Instructor D emphasized how the content learned can be practically applied at the beach or swimming pool, instilling confidence in students and ensuring that they have a safe learning experience.

> *I provide VR experiences and have students take quizzes afterward. If I show a problem and ask a few students for an answer, I make sure to explain it according to the students' levels, providing clear reasons as to why a particular option is correct or incorrect. I think quizzes are essential for keeping students focused. Because the students were not familiar with survival swimming, we evaluated them using relatively simple questions. Moreover, I emphasize how students can apply what they have learned today at beaches or swimming pools. For example, I clarified that even by remembering the CPR sequence, they could save someone's life. Thus, I conclude the class.* (Instructor D)

Instructor J employed quizzes in VR-based swimming survival lessons to support student learning. These quizzes help assess students' understanding of the material and ensure that they comprehensively grasp the lesson content. During these quizzes, Instructor J tailored explanations to the students' levels, clearly stating the reasons behind correct and incorrect answers. This approach motivated students to engage with the material and build their understanding. Instructor J also used quizzes as a motivating factor, as students needed to perform well to participate in future VR lessons. This approach allows for continuously checking students' understanding and offers VR experiences to reinforce their learning.

> *Quizzes are also important. When students answered the question, "What is a shallow dive?" for example, I will adjust my explanation according to each student's level and explain why a particular answer is correct or incorrect. I think quizzes are essential to keeping students focused. The students did not have much exposure to swimming; therefore, we evaluated them using relatively simple questions. Moreover, I emphasize that students can continue to participate in VR lessons only if they perform well on these quizzes. This was a motivating*

> *factor. I continue to check whether students understand well and provide them with the opportunity for VR experiences to reinforce their learning.* (Instructor J)

4.4. Understanding of Learners

"Understanding of Learners" is a core competence in the ICT-TPACK model, where teachers design lessons by considering the characteristics and needs of learners. Teachers can effectively use ICT, provide tailored education, and adapt their teaching based on learners' prior knowledge, learning styles, interests, and special educational requirements.

Additionally, continuous adjustments and improvements in teaching can be made based on learner feedback and assessments. "Understanding of Learners" is essential for implementing learner-centered teaching [29].

Instructor I's statement reflects the TPACK theory's perspective, considering learners' capabilities and experiences. First, learners were categorized into three groups, recognizing the importance of acknowledging their diversity and experiences. Furthermore, Instructor I emphasized the importance of floating in survival swimming and the principle of exerting force when the legs do not touch the ground in the water. This perspective plays a crucial role in enhancing learners' safe and effective survival swimming skills while considering the "Learner" dimension of the TPACK theory.

These findings underscore the importance of considering the diversity and experiences of learners when designing and providing VR-based survival swimming education using the TPACK theory. It actively promotes a learner-centered approach.

> *Always check if there are friends who are good at swimming, friends who are friendly with water, or friends who cannot swim and are not friendly with water. In swimming, the most important task is to float in water. When one's legs do not touch the ground in water, one should exert force to stay afloat and release them. If the robot can float properly, it is considered successful. Even when we take a lifeguard qualification test, going to an experienced person is dangerous. When you consider that everyone panics when they fall into the water, you realize that exerting force is the key to water. Therefore, I hope that everyone knows that they should not exert force in the water even if they have to repeat it.* (Instructor I)

Instructor K emphasized the importance of adjusting the teaching approach based on learners' levels. For instance, they first taught younger students how to turn on VR, and then proceeded with a more comprehensive explanation of VR usage. By dividing education based on learners' levels, waiting times could be reduced, resulting in more effective teaching. Instructor K's approach emphasizes learner-centered education that tailors education to individual needs.

> *I explain things in stages according to the students' levels. Even if I teach everyone how to turn on VR and how to use VR as a whole, some take longer to start, while others understand quickly and start early. As a result, students who finish early have no choice but to wait for those who start late and may find it boring. Therefore, I preferred to break down the explanation into stages according to the students' levels. If you go to a lower-grade class, I explain how to turn on the VR. Once everyone has turned it on, I move on to the next explanation. The older students understood everything simultaneously. Therefore, I think that explanations according to the students' levels can reduce the time students spend waiting and make the class run more smoothly. There are situations in which students who finish early interfere with students who start late.* (Instructor K)

4.5. Pedagogical Beliefs and Philosophy

The "Pedagogical Beliefs and Philosophy" in the ICT-TPACK model represents a teacher's beliefs and values about education, focusing on learner-centered approaches and accounting for learners' needs and abilities. Teachers also aim to promote collaboration among learners and facilitate inquiry-based learning [29].

Instructor J emphasized the diversity in manuals and goals for traditional swimming classes, survival swimming classes, VR-based survival swimming, and simulated CPR classes. Furthermore, Instructor J wanted to provide new knowledge and experiences to students through education and make learning enjoyable and memorable. These beliefs aim to improve the educational process, engage students, and help them retain information.

> *There are overall manuals for general swimming lessons, survival swimming lessons, and VR survival swimming and simulator CPR classes. General swimming aims to make the form look nice, whereas survival swimming sets the secondary goal of overcoming the fear of water and becoming familiar with it. When conducting VR survival swimming and simulator CPR classes, I want to provide students with new information. Since various companies conduct survival swimming lessons in unique ways, I think that students should enjoy and remember the parts that they must grasp.* (Instructor J)

Instructor E strives to conduct classes in a way that stimulates students' inquiries rather than simply delivering information. This approach highlights the importance of engaging students in logical thinking, asking questions, and promoting learning. By continually asking "why", students are encouraged to make the learning process more meaningful and prevent the class from becoming monotonous, thereby increasing their motivation.

> *Survival swimming consisted of 12 sessions, and the content taught in each session differed. There will be differences in teaching methods and the way classes are conducted, depending on the instructors. However, I avoided lessons that flowed spontaneously. I always ask students the question, "Why?" Why is it necessary to understand content properly? I think that we can miss essential parts of a section if we simply overlook it. Students must stimulate their inquiry skills. One-sided teaching is boring. I think a good class encourages students to think.* (Instructor E)

This study assessed VR-based survival swimming instructors' competencies as educators, and evaluated competencies in TCK, TPK, PCK, understanding learners, and pedagogical beliefs. These align with CK, PK, ICT knowledge, learner knowledge, and educational beliefs in the ICT-TPACK model. Our results suggest that participating VR and simulator-based survival swimming instructors improved their competitiveness. The results of this study are summarized in Table 4.

Table 4. Teaching competencies for VR-based survival swimming instructors.

Technological Content Knowledge (TCK)	
Aspect	Details
Content Utilization	Use of media and instructional materials, adjusting learning content, motivation induction, utilizing VR content appropriate for learning objectives.
Equipment Preparation	Understanding educational media, preparedness for lessons, managing physical environment, preparing VR devices, conducting pre-checks.
Addressing Dizziness	Using supplementary materials, knowledge about learners, encouraging participation, utilizing 3D content and breaks for VR dizziness.
Pedagogical Content Knowledge (PCK)	
Aspect	Details
Creating a Learning Environment	Maintaining lesson direction, creating effective environments, managing lesson flow to maintain focus and prevent disturbances.
Enhancing Student Engagement	Encouraging questions and answers, knowledge of teaching strategies, fostering teacher–student relationships, using questions and games to simulate realistic environments.
Technological Pedagogical Knowledge (TPK)	
Aspect	Details
Setting Appropriate Learning Objectives and Guidelines	Subject knowledge, explanation skills, interconnections between contents, ensuring comprehension of VR session and content connectivity.
Educational Assessment	Knowledge about assessment, developing assessment plans and tools, using quizzes and feedback to reflect VR content and improve future lessons.
Understanding Learners	
	Details
	Customizing learning experiences based on each learner's prior knowledge, interests, and special requirements, adjusting teaching methods to learner levels.
Pedagogical Beliefs and Philosophy	
	Details
	Encouraging active learning, inquiry, and collaboration, fostering an inquiry-based environment, aiming for educational experiences that are enjoyable and memorable.

5. Implications

5.1. Theoretical Implications

The research findings on the pedagogical competence of VR-based survival swimming instructors through the TPACK framework present several theoretical implications for educational technology and pedagogy.

First, the emphasis on TCK underscores curriculum developers' need to integrate technological tools seamlessly with subject matter. This integration should consider the alignment of technology with the specific educational content and the pedagogical strategies that leverage technology to enhance learning outcomes [60]. The findings suggest a model for curriculum design where technology is not an afterthought but a core component of the educational framework, tailored to specific learning objectives.

Second, the importance of preparing equipment and addressing technological challenges, such as VR-induced dizziness, highlights the need for comprehensive professional development programs for educators. These programs should focus on the operational aspects of technology and pedagogical strategies to mitigate technology-induced challenges. Educator preparedness extends beyond familiarity with devices and includes strategic planning for technology integration, troubleshooting, and alternative instructional strategies to accommodate diverse learner needs [61,62].

Third, the research findings suggest expanding the TPACK framework to include considerations that are unique to immersive technologies like VR. This includes developing competencies in managing the physical aspects of technology use (e.g., preventing dizziness, equipment management), and creating immersive and interactive content that aligns with pedagogical goals. Therefore, the traditional TPACK framework may be extended to include a dimension that addresses the physicality of technology use in education [63].

Fourth, the findings related to pedagogical beliefs and philosophy suggest that instructors' beliefs about teaching and learning significantly influence how technology is integrated into the classroom. This highlights a theoretical implication where technology integration should not be approached purely from a technical standpoint but should also consider the pedagogical beliefs and philosophies that guide educators' practices [29]. Technology integration in education should support and enhance these pedagogical beliefs rather than contradict them.

Fifth, the research findings support the potential for broader applications of VR technology across different educational sectors beyond physical education. It prompts further research into how VR can be utilized effectively in subjects that traditionally rely on more theoretical or abstract teaching methods and how these approaches can be reimagined with immersive technology.

In summary, these research findings contribute to the theoretical understanding of how the TPACK framework can guide the effective integration of VR technology in survival swimming instruction. By highlighting the importance of TCK, PCK, TPK, an understanding of learners, and pedagogical beliefs, this study provides insights for educators, instructional designers, and policymakers aiming to leverage VR technology to enhance educational outcomes in physical education and beyond.

5.2. Practical Implications

The research findings on the pedagogical competence of VR-based survival swimming instructors, analyzed through the TPACK framework, present several practical implications for educators, instructional designers, and policymakers. Here are some key practical implications derived from the study.

First, the significance of TCK and equipment preparation in VR-based education highlights the need for enhanced training programs for instructors. These programs should equip educators with the skills to select appropriate VR content, manage VR equipment, and troubleshoot technological issues. Practical training should also include strategies to mitigate VR-induced dizziness, emphasizing the health and safety of students during immersive learning experiences.

Second, the findings underscore the importance of integrating VR technologies within the curriculum in a way that aligns with educational goals. Curriculum developers should work closely with technologists and educators to create immersive and interactive VR content that complements teaching objectives. This involves a multidisciplinary approach to curriculum design, where technological tools are seamlessly woven into the educational content to enrich the learning experience.

Third, the individualized nature of VR learning experiences calls for innovative assessment strategies that accurately measure student learning outcomes. Educators should develop and implement assessment tools compatible with VR environments, enabling the evaluation of students' skills, knowledge, and competencies in an immersive context.

Fourth, the practical application of VR in education must include strict health and safety protocols to manage potential risks associated with prolonged use of VR, such as eye strain, dizziness, and disorientation. Schools and educational institutions should establish clear guidelines and support systems to ensure the wellbeing of students engaging with VR technologies.

6. Conclusions

This research provides a comprehensive analysis of the pedagogical competencies required for VR-based survival swimming instructors through the TPACK framework. The findings underscore the importance of integrating technological, pedagogical, and content knowledge to enhance the effectiveness of VR-based survival swimming instruction. By exploring the dimensions of TCK, PCK, TPK, an understanding of learners, and pedagogical beliefs, this study provides valuable insights into the competencies that instructors need to effectively use VR technology in educational settings.

Despite its contributions, this study has several limitations. First, the sample size was relatively small and limited to instructors in South Korea, which may affect their generalizability to other contexts or regions. Second, the research relied heavily on self-reported data from interviews, which may introduce bias or limit the depth of insight into the actual instructional practices and challenges faced by instructors. Third, the study focused predominantly on the instructor's perspectives, with less emphasis on the experiences and outcomes of students engaging with VR-based survival swimming instruction. Fourth, since this study was conducted with only one of the three major companies' software for teaching VR-based survival swimming classes, different results may be obtained from the software of the other two companies.

Also, future research should focus on refining the use of VR to simulate water safety scenarios, specifically by exploring the gap between VR simulations and real-world conditions. This includes developing mixed-reality scenarios that more closely mimic real-life unpredictability and integrating practical exercises to enhance critical thinking and decision-making skills. Such studies will help create a more effective VR-based curriculum that prepares students better for real-world emergencies.

In conclusion, while this study lays the groundwork for understanding the pedagogical competencies required for effective VR-based survival swimming instruction, there is a clear need for further research to address its limitations and expand our knowledge in this innovative area of educational technology. By continuing to explore and refine the integration of VR in educational settings, educators and researchers can further enhance the learning experiences and outcomes for students in survival swimming and other disciplines.

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