Kashihara, A. et al. (Eds.) (2024). Proceedings of the 32nd International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

Enhancing Health Education and Learning Motivation in Primary Students Through Augmented Reality and Game-Based Learning: A Case Study

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Abstract: The integration of technology in education enhanced student engagement and learning efficiency, particularly in challenging subjects like health education, where motivation often posed a barrier. Augmented reality (AR) was one such technology that created interactive learning experiences, allowing students to explore subjects dynamically and visually. By incorporating these tools, educators fostered a supportive learning environment that motivated students to approach their studies with greater enthusiasm. This study examined the impact of integrating AR with game-transformed inquiry-based learning (GTIBL) on primary-level students' conceptual understanding and learning motivation in health education, focusing on the bone and muscular systems. The research involved 23 fourth-grade students from a public primary school in northeastern Thailand and used a mixed-methods approach that included pre- and post-tests for conceptual understanding, learning motivation surveys, and interviews. The findings showed significant improvements in students' conceptual understanding and learning motivation, particularly in career motivation and self-efficacy. However, the study found no significant changes in intrinsic motivation, self-determination, and grade motivation, indicating that while AR and gamification were beneficial in some aspects of learning motivation, their impact was limited in cases where students already held strong pre-existing beliefs. These results suggested that integrating AR and gamification into health education could be a valuable tool for enhancing learning outcomes and motivation, especially in fields that require complex understanding and active engagement.

Keywords: AR, gamification, learning motivation, educational technology

1. Introduction

Today's technology changed education delivery by increasing participation and efficiency. This was particularly evident in complex and difficult subjects like health education, where many students struggled due to a lack of motivation. Technologies such as interactive videos, online simulations, and virtual classrooms made learning captivating and simple to understand. These tools enabled students to learn in a way that matched their learning styles and facilitated comprehension (Selwyn, 2016; Clark & Mayer, 2016). By integrating technology into the learning process, teachers fostered a positive learning environment that encouraged students to study with enthusiasm (Johnson et al., 2016).

Augmented reality (AR) was a technology that enhanced learning by capturing digital data in the real world. AR turned difficult topics into captivating experiences for students in health education by allowing them to view and interact with content more effectively (Bacca et al., 2014). For example, students used AR to explore the human body using 3D models of internal organs and learned how they worked. In this way, students understood complex content more easily (Dünser, Grasset, & Billinghurst, 2012). AR also enabled students to

engage in challenging content through practical learning. As a result, students who perceived traditional teaching methods to be inadequate found this method beneficial (Billinghurst & Dünser, 2012).

The integration of AR with gaming enhanced the benefits of both technologies by boosting student motivation and engagement. Gameplay involved incorporating game-like elements such as scores, badges, challenges, and leaderboards into learning activities to make them more enjoyable and rewarding (Deterding et al., 2011). Applying AR-based gameplay to health education transformed complex topics into interactive experiences, allowing students to learn through play and exploration (Huang & Soman, 2013). This approach not only made learning more enjoyable and relevant but also fostered a competitive and collaborative environment where students worked together and strived for personal success. By tapping into students' natural drive for challenge and achievement, AR and gaming helped sustain their interest and commitment to learning, even on initially challenging topics (Ibáñez et al., 2014). Integrating AR and gamification into health education addressed understanding and motivation challenges by creating interactive and immersive learning experiences that helped students grasp complex concepts and retain information effectively. This study employed augmented reality (AR) with game-transformed inquiry-based learning (GTIBL) to enhance students' learning motivation and comprehension in health education.

2. Literature Review

2.1 Augmented Reality in Education

Augmented reality (AR) was a technology that brought digital information into the physical world, providing users with an interactive and immersive experience. Over the years, AR became a valuable tool for enhancing academic learning experiences. Integrating AR into the learning environment showed promise in improving student engagement and motivation by making learning more interactive and visually appealing (Akçayır & Akçayir, 2017). Previous studies found that applying AR in scientific studies enabled students to view complex concepts, such as solar systems or three-dimensional human anatomy, which led to better understanding and retention of knowledge (Kerawalla et al., 2006). Similarly, in mathematics, AR allowed the visualization of geometric shapes and functions, enabling students to manage and explore them in real time, which enhanced spatial reasoning skills (Cheng & Tsai, 2013). However, researchers noted challenges in AR learning environments, such as participant cognitive overload and the need for effective methods to construct the presented learning materials (Wu et al., 2017).

2.2 Gamification in Education

Gamification involved using game design concepts from a non-game perspective to motivate and capture students' attention. Education uses gamification to enhance the learning experience by incorporating elements like scores, badges, leaderboards, and challenges into the classroom (Deterding et al., 2011). Studies showed that gamification enhanced student motivation and involvement by leveraging both internal and external stimuli. For instance, Domínguez et al. (2013) found that integrating game components into an online learning platform led to higher levels of student engagement and satisfaction. Similarly, Hamari, Koivisto, and Sarsa (2014) reported that gamification positively impacted learning outcomes by promoting competition and interaction among students. Gamification also supported learning by allowing students to progress at their own pace and receive immediate feedback on their performance, aligning with the principle of learning comprehension, where students achieved a deeper understanding (Kapp, 2012). Furthermore, since students often collaborated and competed with peers, gamification in the learning environment fostered a sense of community and belonging, enhancing social learning (Sailer et al., 2017).

2.3 The Integration of AR and Gamification in Education

The combination of AR and gaming held outstanding potential to transform educational behavior by creating immersive and engaging learning experiences. This collaboration between technologies enhanced student motivation and learning outcomes by providing an interactive environment in which students could explore experiments and receive real-time feedback. Several studies investigated the integration of AR and gaming in educational settings. For example, Ibáñez et al. (2014) utilized an AR system with game elements for teaching physics, enabling students to manipulate virtual objects and observe the effects of physical forces, leading to improved learning outcomes. Moreover, the review of empirical studies indicated that students exposed to gamified AR applications in health education showed significant improvements in motivation, participation, and academic performance compared to traditional teaching methods. This approach proved particularly effective in fostering collaboration, enhancing critical thinking, and promoting a positive attitude toward learning (Lampropoulos et al., 2022).

3. Research Methodology

3.1 Research Design

The research design of this study employed a mixed-method approach to investigate the impact of AR with GTIBL on primary students' conceptual understanding and learning motivation. Additionally, individual interviews were conducted after class to collect qualitative data.

3.2 Participants

The participants in this study were fourth-grade students who regularly used technology and mobile devices to learn, with an average age of 9 years old, from a public primary school located in the northeastern region of Thailand. A total of twenty-three students participated in this study. These students received an AR with GTIBL approach. To maintain consistency in content delivery and minimize any potential impact on student outcomes, the same teacher was responsible for instructing both classes.

3.3 Research Instruments

This study used both pre- and post-conceptual understanding tests to evaluate conceptual understanding in health education. The test consisted of ten multiple-choice questions, each with four answer choices, and the maximum score was 10. The reliability was 0.77, indicating a high level of internal consistency. The pre-test aimed to determine the students' prior knowledge of the bone and muscular systems, while the post-test aimed to evaluate their conceptual understanding after the learning activity.

This study also used health education motivation surveys, based on the Science Motivation Questionnaire II (Glynn et al., 2011), which Srisawasdi (2015) translated into Thai. In this study, the researcher adapted the questionnaire from social cognitive theory, substituting the word "science" with "health education" to create a discipline-specific version. The questionnaire contained 25 items in Thai, each scored on a five-point Likert scale. On the scale, 5 represented 'always,' 4 represented 'usually,' 3 represented 'sometimes,' 2 represented 'rarely,' and 1 represented 'never.' The questionnaire was divided into five dimensions: intrinsic motivation (IM), career motivation (CM), self-determination (SD), self-efficacy (SE), and grade motivation (GD). Intrinsic motivation examined learning activities that were interesting, curious, relevant, meaningful, and enjoyable. Career motivation included securing a good job, career advancement, and other career-related goals. Self-determination assessed the perceived challenges of learning, effective preparation, effort investment, time

commitment, and strategy use. Self-efficacy is defined as confidence in achieving excellent scores, performing well on tests, gaining knowledge, and understanding content. Grade motivation focused on achieving high grades, grade-related concerns, and the significance of grades. The results of the Thai version of the health education motivation surveys showed that Cronbach's alpha values of five dimensions provided by 0.79, 0.81, 0.81, 0.89, and 0.85, respectively. The Thai version of the motivation survey had an overall Cronbach's alpha value of 0.92 (Srisawasdi, 2015). Lastly, the interview questions consisted of five questions based on health education motivation surveys; each question covered all five aspects of learning motivation.

3.4 Data Collection

Before the learning approach, students completed a pre-test, which consisted of a conceptual understanding test and health education motivation surveys for 50 minutes. Afterward, students participated in an AR with GTIBL approach adapted from the game-transformed inquiry learning approach (Srisawasdi & Panjaburee, 2019).

During the pre-AR gaming phase, the teacher encouraged students to engage with open-ended questions related to the content they would explore in the AR gaming phase for 50 minutes. In the second phase, the AR gaming phase, the teacher guided students through the game procedures, materials, and rules for 50 minutes. In the final phase, the post-gaming phase, students worked together to summarize the knowledge they had gained from the AR gaming phase for 50 minutes. After completing the three phases of learning, students took a conceptual understanding test and health education motivation surveys, followed by a 10-minute individual interview with each student, as shown in Figure 1.

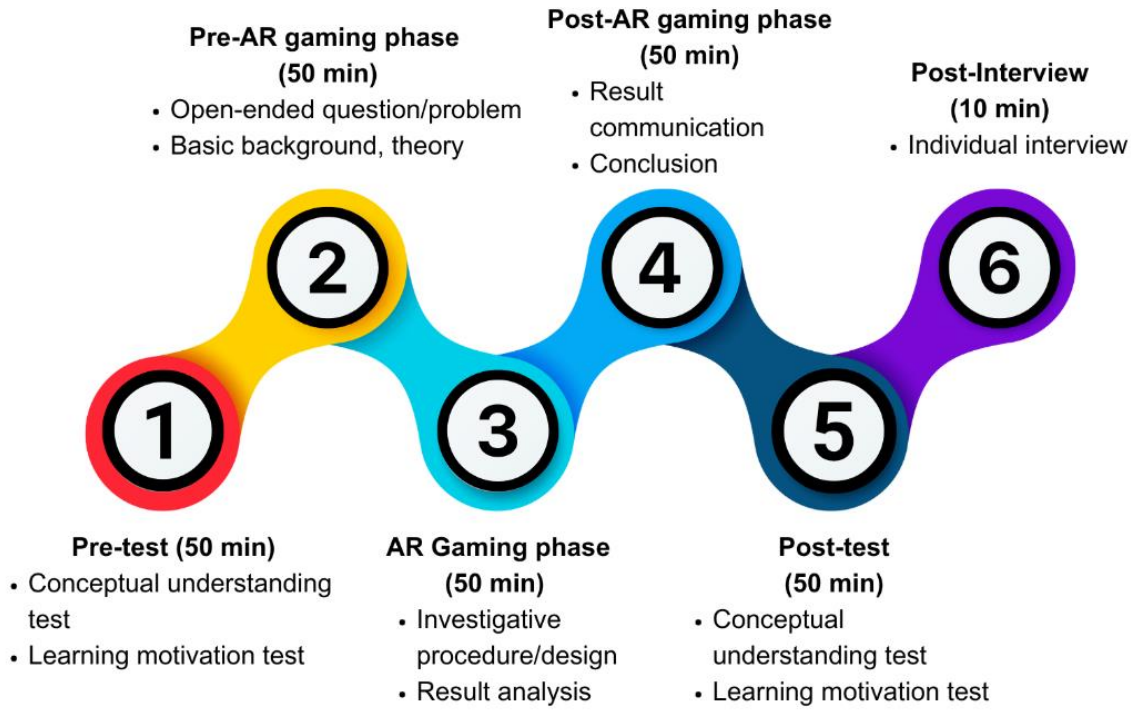

Figure 1. Research procedure adapted from Srisawasdi & Panjaburee (2019).

3.5 An Example of AR Game-Transformed Base Learning

3.5.1 AR Cards

The researcher created all AR cards (such as answer cards, question cards, and function cards) using the Zapworks website. Students scanned the QR code on the back of the AR

cards using a portable device's camera and then pointed at the front of the cards to identify bones and muscles with their names displayed on the screen, as shown in Figure 2.

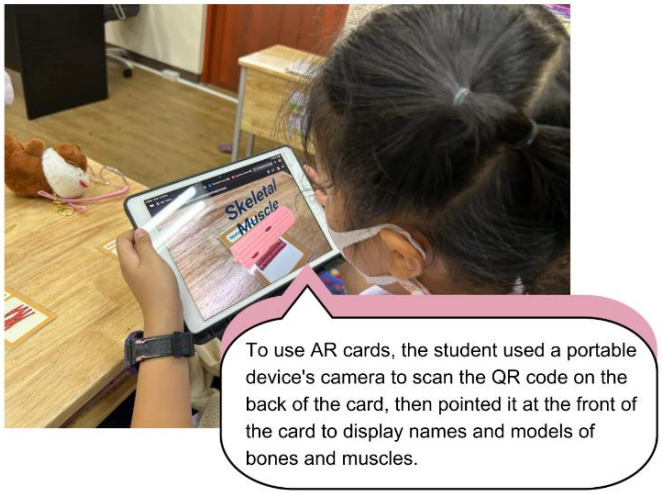

Figure 2. Example displayed of AR answer cards.

3.5.2 AR with Game-Transformed Inquiry-Based Learning Approach

The AR with GTIBL approach included a pre-AR gaming phase, an AR gaming phase, and a post-AR gaming phase. In the pre-AR gaming phase, the teacher introduced the topic with open-ended questions and problems, providing background information to set the context. During the AR gaming phase, students interacted with a game that served as a cognitive tool, allowing them to explore, investigate, and gather data related to the scientific concepts through engaging gameplay. Finally, in the post-AR gaming phase, students reflected on their experiences, discussed their findings, and communicated their scientific arguments with peers and the teacher, reinforcing their learning and deepening their understanding of the concepts explored during the game.

The game commenced with the division of students into six groups, each equipped with six answer cards. As shown in Figure 3, each group member played the game separately at the tables.

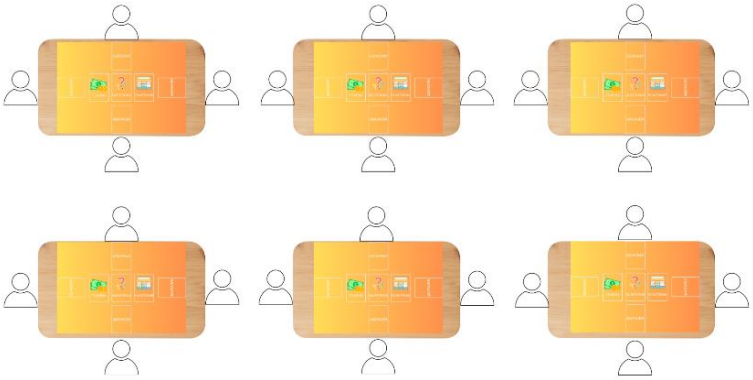

Figure 3. Tables and seating plan.

For the game's instructions at each table, all students were required to answer the question cards on the playmat, as shown in Figure 4. Each question card had an answer on the back, which revealed by using the portable device's camera. If students answered correctly, they received one cash token. The students then used the cash to purchase AR function cards for their teams. After the game had concluded, students returned to their teams and gathered their function cards, which revealed by using the portable device's camera as hints to complete the group worksheet in the post-AR gaming phase.

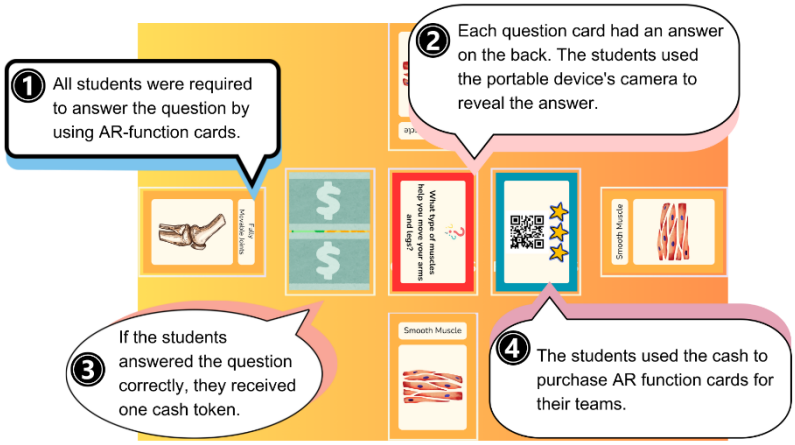

Figure 4. Game's playmat and set up.

4. Result and Discussion

Means and standard deviations represented the average and spread of values, respectively. A paired sample t-test was used to examine the conceptual understanding before and after the approach. A repeated measures MANOVA was used to assess the differences in multiple dependent variables across various time points within subjects. Data analysis was performed using IBM SPSS statistical software version 29.

4.1 Conceptual Understanding

According to Table 1, the study found a significant statistical difference between the pre-test and post-test. The mean score of pre-test was 6.22 with a standard deviation of 1.93, and the mean score of post-test score was 7.57 with a standard deviation of 1.78.

Table 1. *Statistical Results of Paired Sample t-test on Students' Conceptual Understanding*

Variable	N	Pre-test		Post-test		*t*-score	*p*-value
		Mean	S.D.	Mean	S.D.		
Conceptual understanding	23	6.22	1.93	7.57	1.78	-3.81	<0.001***

*** $p<0.001$

Table 1 demonstrated that students who engaged in an AR with GTIBL approach had a better conceptual understanding and performed better after learning. According to Kapp (2012), gamification was consistent with the principle of learning comprehension, in which students achieved a high level of understanding.

This evidence demonstrated that integrating AR with GTIBL approach could have a greater effect on fostering students' health education understanding of bone and muscle systems. Similar to the findings of Ibáñez et al. (2014), they used an AR system that incorporated games for teaching physics, which allowed students to manage virtual objects and observe the effects of physical force, leading to better learning outcomes.

4.2 Health Education Learning Motivation

Table 2 presented the impact of AR with GTIBL learning on health education motivation. There was a statistically significant difference between the pre-questionnaire and post-questionnaire for career motivation (CM) (12.78±3.92 and 15.91±5.39, respectively, p = 0.006) and self-efficacy (SE) (15.04±2.77 and 16.83±2.89, respectively, p = 0.004). This evidence suggested that the integration of AR with GTIBL approach could have had a more significant effect on students' motivation to learn. Similarly, Lampropoulos et al. (2022) reported that students

exposed to gamified AR applications in health education showed significant improvements in motivation. However, there was no statistically significant difference between the pre- and post-questionnaires for intrinsic motivation, self-determination, and grade motivation.

Table 2. *Statistical Results of Repeated Measures MANOVA on Students' Learning Motivation*

Scale		Pre-questionnaire		Post-questionnaire		F-score	η^2	*p*-value
		Mean	S.D.	Mean	S.D.			
Learning Motivation	IM	14.87	4.17	16.17	5.00	1.99	0.08	0.17
	CM	12.78	3.92	15.91	5.39	9.26	0.30	0.006*
	SD	14.04	4.22	15.87	4.05	2.49	0.10	0.13
	SE	15.04	2.77	16.83	2.89	10.45	0.32	0.004*
	GM	16.04	5.1	16.43	5.39	0.21	0.01	0.65

*$p<0.05$

As outlined in our data collection methodology, we conducted the research by qualitatively analyzing data gathered through after-class interviews. In this section, we presented a sample of the collected data based on recordings of interviews with three students.

4.2.1 Intrinsic Motivation – IM

In this section, intrinsic motivation was defined as engaging in a behavior or activity because it was inherently interesting, enjoyable, or satisfying, rather than being driven by external rewards or pressure. The question posed to the students was: "What did you think about your health education class? Was it fun, interesting, and how did it relate to your daily life?"

Student A responded, "It felt better and more fun than usual," Student B said, "It was interesting," and Student C remarked, "It was fun, better than ever." These comments indicated that students were already accustomed to regularly using media and technology. Therefore, intrinsic motivation might not have significantly increased.

4.2.2 Career Motivation – CM

In this section, career motivation was defined as the drive or desire that influenced an individual's behavior and decisions in their professional life. It encompassed the reasons why people chose certain careers, strived to achieve career goals, and continued to grow in their jobs or professional development. The interview question asked was: "How do you think learning about health education can help you have a better job or be successful when you grow up?" Student A responded, "For those who want to be doctors, it would help a lot," Student B said, "I think it would help you have a good career," and Student C replied, "Consider a career in medical field."

These responses indicated that a significant number of students aspired to pursue careers in medical science. When students used augmented reality (AR) to enhance the visual aspect of their learning and gamification techniques to engage more effectively with challenging topics, their career motivation increased. Domínguez et al. (2013) found that integrating game components into learning helped students achieve higher levels of engagement and satisfaction.

4.2.3 Self-Determination – SD

In this section, self-determination was defined as an individual's ability to make choices and manage their own life, emphasizing autonomy and the capacity to make decisions based on personal will rather than external pressures. The interview question posed was: "What do you think you need to do to learn health education class well? For instance, do you think you need

to work hard, engage in exercises, or dedicate more time to studying?" Student A responded, "I must study hard, not talk to friends, and review the knowledge I have learned," Student B said, "I used other techniques to help me with my studies," and Student C commented, "I must spend a lot of time reading books."

The students' comments suggested that the AR gamification intervention might have reinforced their existing beliefs about the importance of hard work and strategic study practices. Although the quantitative results did not show a statistically significant change in self-determination, these qualitative insights indicated that the intervention might have had a subtle but meaningful impact on students' attitudes towards their learning.

4.2.4 Self-Efficacy – SE

Self-efficacy referred to an individual's belief in their ability to successfully perform the behaviors necessary to achieve specific outcomes. The interview question posed was: "How did you control yourself to get good grades in health education class? Were you interested or excited to learn new things about this subject?" Student A responded, "It made me want to discover new things." Student B said, "It made me not talk to my friends next to me, but I also didn't want to learn new things," and Student C commented, "It made me want to learn more about other things; I wanted to review the past too."

These comments suggested that AR-gamification-based learning might have encouraged students, leading to a significant increase in self-efficacy through game elements. This finding aligned with previous studies, which showed that gamification supported learning by allowing students to progress at their own pace and receive immediate feedback on their performance (Kapp, 2012).

4.2.5 Grade Motivation – GM

Grade motivation was defined as the drive or incentive that students felt to achieve high grades in their academic work. The interview question asked was: "Why did you think getting excellent grades in health education class was important? Did you have any goals to score higher than others?" Student A responded, "Grades were important because they showed that we studied hard," Student B said, "I wanted to do well in exams," and Student C commented, "I aimed to get a higher score than others." Many students also emphasized the importance of grades, noting that they served as indicators of their study skills and learning behaviors.

Based on the students' comments, it could be inferred that they already had significant concerns about their grades, which may explain why grade motivation did not significantly increase.

5. Conclusion and Limitations

This study aimed to evaluate the impact of integrating AR with GTIBL learning on primary-level students' conceptual understanding and motivation to learn health education topics, specifically the bone and muscular systems. The findings indicated that the AR with GTIBL approach significantly enhanced students' conceptual understanding, as evidenced by the improved post-test scores compared to the pre-test results. This suggested that the interactive and immersive nature of AR, combined with the engaging elements of gamification, could effectively facilitate learning in complex and traditionally challenging subjects. Additionally, the study revealed significant improvements in students' career motivation and self-efficacy, indicating that the use of AR and gamification positively influenced students' motivation to learn and confidence in their ability to succeed. However, the study found no significant statistical changes in intrinsic motivation, self-determination, and grade motivation, suggesting that while the AR gamification approach was effective in certain motivational domains, its impact might have been limited in areas where students already possessed strong existing beliefs or behaviors.

In conclusion, the integration of AR and gamification into health education offered promising opportunities for enhancing students' learning outcomes and motivation, particularly in topics requiring complex understanding and active engagement. This approach could be a valuable tool in addressing the challenges of student motivation and comprehension in health education and potentially other academic disciplines. Despite the promising findings, this study had several limitations. First, the sample size was small, which may have restricted the generalizability of the results to other educational settings or student populations. Second, the study focused on a specific topic within health education, and the effects of AR and gamification might vary across different subjects or content areas. Third, the study relied on self-reported measures of motivation, which could have been subject to bias and might not fully capture the complexity of students' motivational processes.

Additionally, while the study demonstrated improvements in conceptual understanding and certain motivational factors, it did not explore the long-term effects of the AR gamification approach on student learning outcomes or motivation. Future research should consider larger and more diverse samples, explore different academic subjects, and include longitudinal studies to assess the sustained impact of AR and gamification on student's learning and motivation.

Acknowledgements

The author would like to express gratitude to all participants, as well as the Khon Kaen University Demonstration School International Division, Khon Kaen University, for their support of this study. In addition, ethical approval was obtained from the Human Research Ethics Committee of Khon Kaen University (Ref. HE673382).

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