Personalized Inquiry and Game-based Learning Approaches for Supporting University Students' Achievement and Emotional Engagement

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Abstract—**Personalized learning has been widely recognized as an effective approach to address individual student needs; however, many systems face challenges in supporting students to explore content while maintaining motivation and enjoyment systematically. To address these limitations, the Augmented Reality, Inquiry-Based Personalized Gaming (ARIPG) framework integrates the strengths of Augmented Reality (AR), inquiry-based learning, and personalized learning to compensate for the limitations inherent in each approach, resulting in a more coherent and balanced learning model. While AR enhances the visualization and contextualization of abstract concepts, inquiry-based learning promotes active knowledge construction and scientific inquiring, and personalized learning addresses individual differences among learners. By synergistically combining these approaches, ARIPG creates a holistic learning environment that leverages its complementary advantages to support both cognitive and affective learning outcomes. An experiment was conducted in a biochemical university course to evaluate students' learning achievement and the role of emotional engagement. The results indicated that students who learned with the ARIPG approach significantly outperformed those in a conventional personalized gaming environment. Moreover, the findings revealed no significant differences in achievement between students with low and high levels of affection, suggesting that the proposed approach can effectively support diverse learners' emotional engagement.**

Keywords—**higher education, personalized learning, immersive technology, game-based learning, equality education**

I. Introduction

Personalized learning is widely recognized for its potential to address learners' diverse needs by adapting instructional content, activities, and pedagogical strategies to individual characteristics, thereby improving learning outcomes and providing targeted support [1, 2]. Prior studies have demonstrated the effectiveness of personalized systems in enhancing academic performance, such as the personalized e-learning platforms developed by Panjaburee *et al.* [3] for Science, Technology, Engineering, and Mathematics (STEM) education and the eOrientation Moodle plugin proposed by Sáiz-Manzanares *et al.* [4] for early identification of at-risk undergraduate students. Despite these advantages, existing personalized learning systems face notable challenges. In particular, many lack pedagogical strategies that effectively guide learners in the systematic exploration and construction of knowledge [5, 6]. In contrast, learners' motivation and enjoyment often remain limited, leading to reduced engagement and suboptimal outcomes [7–10]. Moreover, the reliance on traditional content formats, such as text and video, may constrain interactivity and hinder immersive learning experiences that connect abstract concepts to real-world contexts. Inquiry-based learning and game-based learning have been proposed as promising approaches to address these limitations. Inquiry-based learning supports active exploration and scientific reasoning [11, 12], whereas game-based learning enhances motivation through challenges and immersive experiences [13–15]. However, learners do not always engage with educational games as intended [16], and expected learning outcomes are not consistently achieved [17]. Although prior research has explored learners' perceptions of educational games [18, 19], the role of emotional engagement in shaping learning performance within personalized learning environments remains underexamined. Augmented Reality (AR) offers a compelling means of enriching personalized learning by providing immersive, interactive experiences that bridge virtual content and real-world applications [20–22]. While AR has shown promise in supporting the visualization of complex phenomena [23], its integration with inquiry- and game-based strategies in personalized learning contexts remains limited. Despite extensive research on AR, personalized learning, and game-based learning, these approaches have predominantly been investigated in isolation. Relatively little attention has been paid to their pedagogically integrated application, particularly to understanding how AR can dynamically support personalized gameplay experiences that influence both learning performance and learner engagement in higher education. Addressing this gap, the present study moves beyond a mere technical combination of instructional technologies by proposing a theoretically informed design framework that intentionally aligns AR affordances with personalization mechanisms and game-based learning principles. This integration is designed to support not only cognitive learning outcomes but also learners' affective experiences. Accordingly, the study contributes to the literature by extending AR research into personalized game-based learning contexts, examining both cognitive (learning achievement) and affective (emotion, enjoyment, and acceptance) dimensions, and providing empirical evidence from higher-education learners. Specifically, this

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study investigates:

(1) Does Augmented Reality, Inquiry-based Personalized Gaming (ARIPG) outperform a Conventional Personalized Gaming (CPG) approach in improving students' learning achievement?
(2) Does learning achievement differ between students with relatively low and high levels of emotional engagement within the ARIPG approach?

The findings confirm a positive relationship between students' learning performance and participation in the proposed educational game. Collectively, these results offer valuable theoretical insights for the development of affect-sensitive personalized learning systems and provide actionable guidance for instructors aiming to adopt AR-supported pedagogies in higher education.

II. Literature Review

A. Personalized Learning Systems with Inquiry and Game-based Learning Approaches

Researchers have shown that personalized learning systems with inquiry and game-based learning approaches can enhance students' learning performance, perceptions, and motivation [24], as well as emotion and cognition [7]. With an inquiry-based learning approach, students are asked to investigate their assumptions and construct their knowledge through an experiment informed by the constructivist theories of John Devery and Jean Piaget. Komalawardhana and Panjaburee [5] show that an inquiry-based online educational game on the science course topic of force and motion for elementary students in grades 4 and 5 could enhance students' learning performance. Srisawasdi and Panjaburee [25] reported that game-transform inquiry-based learning could enhance students' understanding of chemistry learning courses [25]. Dorji *et al.* [24] reported that inquiry-based computer instruction in an electricity course could help students reach their learning goals.

Moreover, many researchers have found that appropriate learning strategies in computer games (e.g. an inquiry-based approach) can support elementary school students' learning performance not only in a general science course [5] but also in social and mathematics courses [26]. However, there are many issues and challenges for researchers in designing the inquiry-based learning activity and in blending and integrating it with the educational game. Few studies were implemented in the applied science course with domain-specific knowledge (e.g., biology or chemistry laboratory classes) to facilitate and motivate future higher education learners. Moreover, AR technology, when combined with inquiry- and game-based learning approaches, would support students' visualization of the real world, thereby enhancing learning performance.

To cope with the above issues, this study has adopted a guided inquiry-based learning approach as the framework for teachers to design and deliver the questions, scientific information background, and procedures for inquiring and exploring AR in DNA bioscience learning. As the specific knowledge, the ARIPG was designed to support the visualization and ensure that the student would receive enough information to execute the learning activity and achieve the learning goal. Based on Michail's study [27], it was highlighted that a "successful" educational game is a learning environment that can help students acquire more knowledge than traditional instruction.

B. Students' Emotions toward an Augmented Reality Inquiry-based Personalized Gaming

Learning is the experience of emotion and cognition [28]. Emotion can positively and negatively affect students' learning motivation [29], prompting them to focus their mental effort and, in certain instances, to strive for higher learning. The technology-mediated learning framework's emotional term (psychological process) (TML-[30]) includes motivation and interest. Furthermore, TML positively affects learning motivation and performance [31, 32]. Motivation plays an importance role in learning achievement [33]. Meaningful learning has been shown to correlate positively with students' performance goals (Goal Orientation). Both extrinsic and intrinsic motivation can influence student engagement with educational technology [34]. According to Ryan and Deci's [35] self-determination theory, a person's feeling of self-determination is influenced by the fulfillment of three basic psychological needs: autonomy, competence, and relatedness. When these psychological needs are met, individuals often demonstrate improved mental well-being and enhanced performance. For self-efficacy, the students' beliefs in their capabilities to organize and execute the course in a particular area of science have been identified as a strong predictor of performance in scientific subjects [33]. Low anxiety could support students' enjoyment and confidence in their learning achievements [27]. If educational games elicit positive emotional responses, they can foster enriching learning experiences and boost academic achievement [36]. Positive correlations have been found between positive emotions and the acquisition of computer knowledge [37]. That is to say, previous studies have only suggested that high emotion leads to high learning performance and low emotion results in low learning performance during gameplay. In other words, there is limited research comparing learning achievement between students with low and high levels of emotion, which contributes to knowledge about enhancing the gaming environment to support all levels of emotion in learning with games. Therefore, in this study, the motivational factors and learning interests will be examined in relation to students' emotions.

C. Students' Enjoyment of an Augmented Reality Inquiry-based Personalized Gaming

During the learning process, students' enjoyment is an important factor in their level of concentration and affective reactions [38, 39]. The study showed that the student's enjoyment is a crucial factor not only of learning achievement [40] but also of user technology acceptance. In terms of technology acceptance, students' enjoyment influenced their perceived ease of use of the in-game system user interface design [16, 41]. Moreover, the greater the enjoyment of ease of use, the greater the acceptance of the technology [42]. On top of that, perceived ease of use and perceived usefulness are important factors in technology acceptance [43]. Venkatesh [42] reported that students' enjoyment correlated with their perceived usefulness, with ease of use mediating the relationship. The higher game level, with more difficulty levels and improved learning effectiveness for students, represented the educational game's success. In addition, the higher the level of enjoyment in a game, the less anxiety and more confidence about their learning achievements. However, some studies found that learning enjoyment did not affect learning effectiveness [44]. Many scholars have studied perceived enjoyment toward the intention to use [45, 46], but few have studied enjoyment toward learning performance. In this study, student enjoyment is defined as a positive, activating achievement emotion experienced during learning activities, consistent with the Control-Value Theory [47]. The academic enjoyment stems from students' appraisals of high control and positive task value, which are known to facilitate deep cognitive processing and sustained engagement [29]. Therefore, it is valuable to understand how low and high levels of enjoyment could affect learning performance in games.

D. Student's Acceptance of an Augmented Reality Inquiry-based Personalized Gaming

Over the past few decades, the Technology Acceptance Model (TAM) has been a key framework for analyzing user behavior in relation to technology adoption [43]. Its primary aim is to explore how external factors, along with users' internal beliefs, attitudes, and intentions, influence their willingness to use a given technology. However, the system's external variable effects may not fit every system. Regarding educational technology, acceptance varies with students' needs, system design, and capabilities. Many researchers used TAM-related theories to predict educational game acceptance. For example, Panjaburee *et al.* [19] employed TAM to assess students' acceptance of personalized e-learning systems for science, technology, and mathematics. Abdullah and Ward [48] examined an extended version of TAM to study e-learning adoption and its influence on students' perceptions. Hsu and Lu [49] found that in online gaming, 80% of behavioral variance could be explained by an extended TAM model, in which ease of use was a stronger predictor than perceived usefulness. Similarly, Ha *et al.* [50] discovered that enjoyment was a better predictor of mobile video game acceptance than usefulness. However, the present study takes a different approach by examining the educational game as an independent variable. Attitude and intention to use are emphasized, as they are among the most frequently cited predictors in studies of educational game acceptance [51]. Our findings suggest that users' practical engagement with digital game systems is shaped by their intention to use the game, their attitude toward playing it, and their motivation to engage. Nevertheless, these attitudinal and intentional factors remain critical in determining learning outcomes. Therefore, this study analyzes the attitudes and intentions that affect students' acceptance.

Accordingly, Fig. 1 shows the study's conceptual framework, comprising four main elements: Emotion, Enjoyment, Acceptance, and Performance. The research examines whether students' affective factors toward personalized learning systems influence their academic performance. To this end, this study examined three categories of the affective domain (i.e., Emotion, Enjoyment, Acceptance), which have been recognized in the literature as highly important [27, 52]. Although each category encompasses a range of variables, this study—among the few to examine the impact of students' emotional responses on performance—selected one key representative variable from each category (Fig. 1). The following sub-sections detail these variables and present the corresponding hypotheses to inform research question 2.

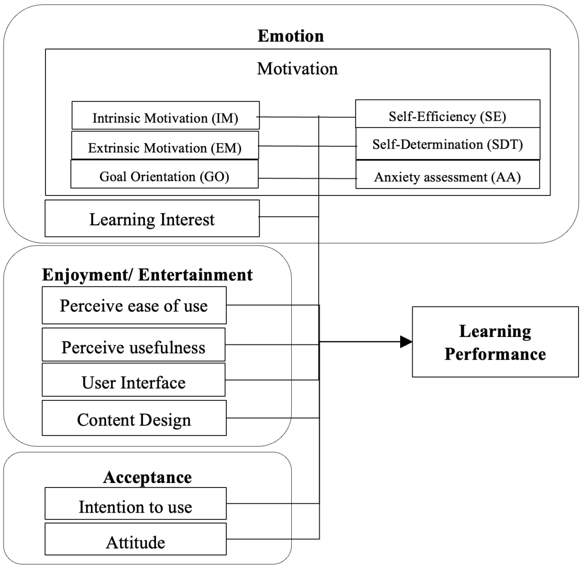

Fig. 1. The study conceptual model.

III. RESEARCH HYPOTHESES

The research hypotheses concern students' learning performance (achievement), enjoyment (emotion), and acceptance (perception). Research Question 1 (comparison between ARIPG and CPG on learning achievement) is directly addressed by Hypothesis H1 as follows:

H1: Students' learning achievement regarding knowledge acquisition through the ARIPG has significantly outperformed the CPG approach.

Moreover, Research Question 2 (differences associated with students' affective and motivational characteristics) is aligned with Hypotheses H2–H4 as follows:

H2a: Students with low Intrinsic Motivation (IM) have equal learning achievement compared to those with high IM through the ARIPG approach.

H2b: Students with low Extrinsic Motivation (EM) have equal learning achievement compared to those with high EM through the ARIPG approach.

H2c: Students with low Goal Orientation (GO) have equal learning achievement compared to those with high GO through the ARIPG approach.

H2d: Students with low Self-Efficacy (SE) have equal learning achievement compared to those with high SE through the ARIPG approach.

H2e: Students with low Self-Determination (SDT) have equal learning achievement compared to those with high SDT through the ARIPG approach.

H2f: Students with low Anxiety Assessment (AA) have equal learning achievement compared to those with high AA through the ARIPG approach.

H2g: Students with low Learning Interest (LI) have equal learning achievement compared to those with high LI through the ARIPG approach.

H3a: Students with low Perceived Ease of Use (PEOU) have equal learning achievement compared to those with high PEOU through the ARIPG approach.

H3b: Students with low Perceived Usefulness (PU) have equal learning achievement compared to those with high PU through the ARIPG approach.

H3c: Students with Low Content Design (CON) perception have equal learning achievement compared to those with high CON through the ARIPG approach.

H3d: Students with low User Interface design (UI) perception have equal learning achievement compared to those with high UI through the ARIPG approach.

H4a: Students with Low Intention to Use (ITU) have equal learning achievement compared to those with high ITU through the ARIPG approach.

H4b: Students with low Attitude (ATT) have equal learning achievement compared to those with high ATT through the ARIPG approach.

IV. Augmented Reality Inquiry-based Personalized Gaming (ARIPG) Approach

This study developed an integrative AR into an inquiry-based personalized gaming approach to support learning performance in a bioscience course on DNA translation and transcription. The game has been implemented using AR technology in a web-based Three.js application. PostgreSQL and Strapi have been used as the database and application programming interface. The 3D simulation with AR technology game has been selected to support the game scenarios. The 3D simulation game was selected as the gaming format to immerse students in realistic experiences of DNA transcription and translation. Using Augmented Reality (AR), this method helps students understand how their learned knowledge applies to real-world phenomena. The approach benefits from the strengths of the scientific inquiry method; it incorporates scientific inquiry learning into this study. Furthermore, progress in computer technology and networking has the potential to make personalized learning an effective approach [53] by enabling support for student differentiation, individual analysis of learner data, and the provision of appropriate suggestions or guidance.

This study designed and developed an AR Inquiry-Based Personalized Gaming (ARIPG) system that integrates a learning diagnosis mechanism with fuzzy rules, an extension of classical set theory that allows elements to exhibit degrees of membership [54], to tailor learning activities based on students' conceptual levels. Three levels of conceptual understanding were identified: well-learned, partially learned, and poorly learned. Students categorized as well-learned were not required to explore that concept further, whereas those categorized as partially or poorly learned were guided to engage with the corresponding content. The system begins with students logging into the game and completing an online pretest to diagnose conceptual learning problems; based on these results, personalized game stages are automatically generated. Each stage introduces inquiry-oriented, open-ended questions, followed by AR-supported exploration and game-based tasks that enable students to visualize scientific concepts, solve problems, and answer related questions. Learners then respond to open-ended questions, reflect on their understanding, and receive further scaffolding from peers' ideas or the teacher's hints. Finally, students consolidate their learning by answering summarized questions, ensuring misconceptions are addressed, and knowledge is reinforced. Through this personalized flow, the ARIPG system integrates adaptive pathways, inquiry-based questioning, immersive AR exploration, game challenges, and collaborative reflection to foster both cognitive and affective learning outcomes.

The learning process of the ARIPG approach starts with an open-ended question game that introduces the stage. The learning environment was developed with a guided-inquiry approach and features five main components. In the open-ended question format, the teacher presents a question through the content management system, which manages the interface within the database system. The system will show the prepared open-ended question relevant to the science situation and ask the student to transition into the gaming stage before the learning and exploration phenomenon is visualized by AR, enabling the game activity as shown in Fig. 2.

Fig. 2. Illustrated interface of open-ended question mode.

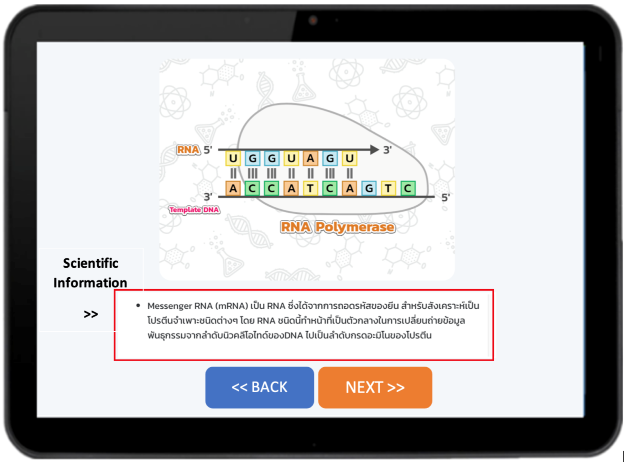

Fig. 3. Illustrated interface of scientific background mode.

In the scientific background mode, the system presents the essential scientific information students need to understand in order to play and win the game successfully. This content is organized and managed by the teacher through the database's content management system, ensuring that all necessary information is available, as shown in Fig. 3.

In the procedure-and-design-of-experiment mode, students are encouraged to investigate scientific phenomena by engaging with the game. This component integrated Augmented Reality (AR), requiring students to explore the

DNA translation and transcription concepts within the game environment. Some mobile phone/tablet models do not support AR mode, so the proposed game approach was designed to support AR and 3D modes to ensure accessibility for all students. The use of AR and 3D in teaching the DNA process helps students develop a scientific understanding by visualizing a rotating virtual DNA model. Throughout the learning activity, students play the game to overcome various challenges, with up to three chances to fail at each stage before the game ends. Each stage consists of three scenarios that students must complete to progress. For example, as illustrated in Fig. 4, during game stage 3—which focuses on Concept 3: mRNA processing—students must identify the correct mRNA base pairs across three scenarios to complete the stage.

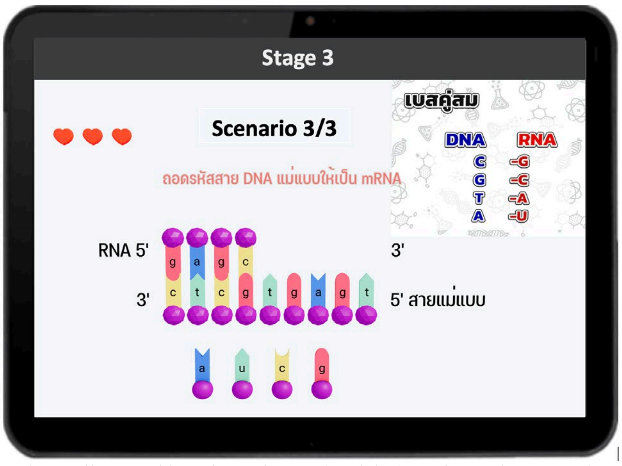

Fig. 4. Illustrated interface of procedure/ design of experiment mode.

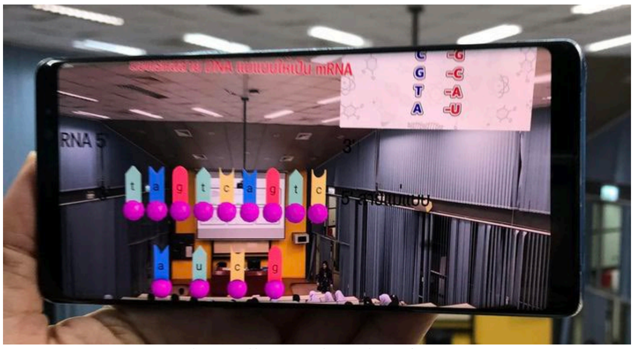

Fig. 5. Illustrated AR interfaces.

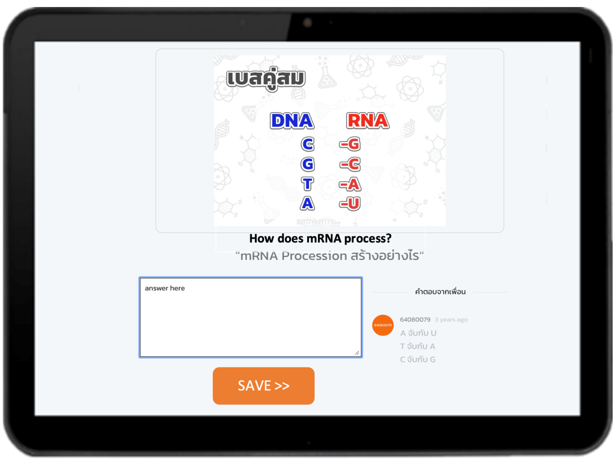

Fig. 6. Illustrated interface of the data and result analysis, communication, and conclusion modes.

Moreover, teachers can provide relevant information to support and facilitate the student during the learning activity. The teacher creates the game's narrative and framework, providing students with essential information to help them investigate scientific phenomena during gameplay, as shown in Fig. 5.

In the data and result analysis, communication, and conclusion modes, information about the student (e.g., recorded data) and key actions during gameplay is re-displayed for analysis. The questions designed to promote collaboration between students and teachers are organized within the communication interface. Additionally, information such as answers, hints, questions, or messages from other players is shown in the guidance area. In this mode, teachers can verify these questions and messages. At the same time, students can review and reflect on the information to reach conclusions by answering a summary question for the next step (Fig. 6).

V. Research Methodology

A. Participants

This study involved undergraduate biochemistry students from five universities across Thailand. A total of 409 students participated and were assigned to two groups: 205 to the experimental group and 204 to the control group. Students in the experimental group engaged in the Augmented Reality-Integrated Personalized Game-based learning (ARIPG) approach, which incorporated Augmented Reality (AR) features and inquiry-based learning activities. Students in the control group followed the Conventional Personalized Gaming (CPG) approach. The control condition used the same gaming software and learning content as the experimental group, but without AR functionality or inquiry-based learning activities. This design allowed for comparison of the added value of AR-supported inquiry elements beyond the baseline personalized gaming experience. All participants completed the assigned learning activities individually. Following the intervention, students completed perception and motivation questionnaires and post-tests. All participants demonstrated basic proficiency in using networked and digital technology tools (e.g., notebooks, tablets, smartphones).

1) Experimental procedure

This study employed a quasi-experimental research paradigm using a pre-test and post-test control group design to evaluate the effectiveness of the AR Inquiry-based Personalized Gaming (ARIPG) system. The design was intended to address two research questions: (1) whether ARIPG outperforms a Conventional Personalized Gaming (CPG) approach in improving students' learning achievement, and (2) whether students' emotional engagement (low vs. high affection) moderates the effectiveness of ARIPG on learning achievement. At the beginning, students were introduced to the instructional objectives, learning goals, and the basic functions of the ARIPG system. They then engaged in a short practice session of the game and completed an initial perception and motivation questionnaire. All students took a 10-minute pre-test to assess prior knowledge of DNA translation and transcription. Following this, the control group studied these concepts using the CPG approach, while the experimental group engaged with the same content through the ARIPG approach during a 200-minute session. After the intervention, all participants completed a post-test to measure knowledge gains and a follow-up questionnaire on perceptions and motivation (10 minutes). Data analysis focused on comparing learning outcomes between groups to evaluate the relative effectiveness of ARIPG and examining the moderating role of students' emotional engagement in influencing achievement.

B. Measuring Tools

Learning achievement was assessed using pre-tests and post-tests. Both tests consisted of 10 multiple-choice items, each worth 1 point, yielding a maximum possible score of 10. The test was designed by two experienced general science teachers to comprehensively cover the key conceptual components of DNA transcription and translation addressed in the instructional activities. All items were reviewed and validated to ensure content relevance and alignment with the learning objectives. The pre-test assessed students' prior knowledge of the target concepts, while the post-test evaluated learning outcomes following the instructional intervention. The same set of items was used for both tests to enable direct comparison of students' performance over time and to capture learning progression on identical conceptual content. Although this approach supports consistent measurement, it may introduce potential testing effects, such as item familiarity or recall.

The perception questionnaire used in this study was adapted from the extended Technology Acceptance Model (TAM) questionnaire developed by Teo [55] and later modified by Komalawardhana and Panjaburee [5]. It comprised 18 items rated on a five-point Likert scale and covered six dimensions: perceived ease of use (PEOU – 2 items), perceived usefulness (PU – 3 items), attitude (ATT – 4 items), game user interface design (GUI – 3 items), content design (CON – 3 items), and intention to use the proposed game-based learning (ITU – 3 items). The scale ranged from 1 (strongly disagree) to 5 (strongly agree). Perceived Usefulness (PU) refers to the belief that the game-based learning system enhances task efficiency and productivity. Perceived ease of use (PEOU) describes the extent to which an individual perceives the system as easy and effortless to use. Attitude (ATT) captures the individual's feelings and opinions toward the game-based learning platform. Intention to Use (ITU) reflects the user's willingness or likelihood to adopt digital game-based learning [56]. The Thai version of the questionnaire showed high internal consistency, with a Cronbach's alpha of 0.960, indicating strong reliability. Furthermore, composite reliability values for each dimension were as follows: PEOU (0.845), PU (0.879), ATT (0.887), GUI (0.854), CON (0.793), and ITU (0.895), all of which demonstrate acceptable levels of internal consistency [57].

The motivation questionnaire used in this study was adapted from Glynn *et al.* [33]. It consisted of 30 items measured on a five-point Likert scale, where 1 indicated "strongly disagree," and 5 indicated "strongly agree." The questionnaire assessed six dimensions of motivation: Intrinsic Motivation (IM), Extrinsic Motivation (EM), Self-Determination (SD), Self-Efficacy (SE), Goal Orientation (GO), and Anxiety Assessment (AA). The Thai version of the questionnaire demonstrated good internal consistency, with a Cronbach's alpha of 0.916. Additionally, the composite reliability scores for each dimension were as follows: IM (0.694), EM (0.709), SD (0.635), SE (0.815), GO (0.738), and AA (0.836), indicating satisfactory reliability across all constructs.

The learning interest questionnaire was modified from the original instrument developed by Hwang and Chang [58] and translated into Thai. It consists of four items, each measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), allowing students to express their level of agreement. The Thai version showed acceptable internal consistency, with a Cronbach's alpha of 0.787.

C. Data Analysis

The first research Hypothesis (H1) was tested using one-way ANCOVA to analyze students' learning performance. Two student groups were studied, with the pre-test as a covariate. To determine the homogeneity of variance, Levene's test was applied, which did not violate $F_{(1, 412)} = 2.667$ ($p > 0.05$). This result indicates that the homogeneity of variance assumption is reasonable for using one-way ANCOVA. Therefore, one-way ANCOVA was conducted to analyze the relationship between students' pre- and post-test scores, with the proposed method as the independent variable, the post-test as the dependent variable, and the pre-test as the covariate.

To examine the potential associations between students' affective performance factors and learning performance (Hypotheses H2, H3, and H4), an exploratory group-comparison approach was adopted. Students were categorized into higher- and lower-level groups based on median splits of their Emotion, Enjoyment, and Acceptance scores. This grouping strategy was employed to facilitate interpretability and to enable straightforward comparisons between students with relatively different affective profiles.

Independent samples t-tests were then conducted to compare learning performance between the higher- and lower-level groups for each affective factor. Prior to analysis, assumptions of normality and homogeneity of variance were examined and satisfied, supporting the appropriateness of the t-test for these comparisons. It should be noted that this analytical strategy was not intended to test moderation effects but rather to provide an initial, exploratory examination of performance differences associated with varying levels of students' affective factors.

VI. Results

A. Learning Performance toward an Augmented Reality Inquiry-based Personalized Gaming

Table 1. One-way ANCOVA results for students' learning performance

Source	SS	Df	MS	F	Partial Eta Squared
Group	48.869	1	48.869	24.836*	0.057
Error	808.714	411	1.968		

* $p < 0.05$

The result of the first hypothesis is shown in Table 1. The experimental group achieved higher post-test scores (Mean = 6.35, SD = 1.506) compared to the control group (Mean = 5.31, SD = 1.560), with $F_{(1, 411)} = 24.836$ ($p < 0.05$, partial eta squared = 0.057: approximately effect 5.7% of the variance in the test scores). This indicates that students who learned through the ARIPG approach demonstrated better learning performance than those taught using the traditional instructional method.

B. Students' Emotion, Enjoyment, and Acceptance toward an Augmented Reality Inquiry-based Personalized Gaming

The H1 result indicates that game-learning values support higher learning performance than CPG instruction. This study will analyze the potential effect of students' performance factors to answer the research Hypotheses (H2, H3, and H4). The descriptive data on research factors and their related items are shown in Table 2.

Table 2. The research factors and their related items descriptive data analysis

Items			Median	Low N	Low %	High N	High %
Students' Emotion	Intrinsic Motivation	IM	21	88	42.93	117	57.07
	Extrinsic Motivation	EM	17.5	66	32.20	139	67.80
	Goal Orientation	GO	20.5	92	44.88	113	55.12
	Self-Determination	SDT	19.5	88	42.93	117	57.07
	Self-Efficacy	SE	18.5	71	34.63	134	65.37
	Anxiety Assessment	AA	10.5	31	15.12	174	84.88
	Learning Interest	LI	18	99	48.29	106	51.71
Students' Enjoyment	Perceive ease of use	PEOU	9	83	40.49	122	59.51
	Perceive usefulness	PU	14	96	46.83	109	53.17
	Content Design	CON	14	99	48.29	106	51.71
	User Interface Design	UI	14	91	44.39	114	55.61
Students' Acceptance	Intention to Use	ITU	13	89	43.41	116	56.59
	Attitude	ATT	18	87	42.44	118	57.56

C. Students' Emotions toward an Augmented Reality Inquiry-based Personalized Gaming

There are 7 items to analyze the students' emotions and motivations (i.e., Intrinsic Motivation-IM, Extrinsic Motivation-EM, Goal-Orientation-GO, Self-Determination-SDT, Self-Efficacy-SE, Anxiety Assessment-AA) and Learning Interest (LI). Table 3 shows the students' emotional hypotheses results of t-test analysis for H2a, H2b, H2c, H2d, H2e, H2f, and H2g. All items of an emotional factor (i.e., IM, EM, GO, SDT, SE, AA, and LI) have indicated no statistically significant difference in students' learning performance between low and high groups. It means that students with low items on an emotional factor have equal learning achievement compared to those with high items, using the ARIPG approach.

Table 3. Hypothesis testing for students' emotions using the t-test

Dependent variable	Students' emotions	Mean (S.D.) Low	Mean (S.D.) High	*T*
Learning Performance (LP)	H2a: Intrinsic Motivation (IM)	6.36 (1.424)	6.34 (1.571)	0.919
	H2b: Extrinsic Motivation (EM)	6.41 (1.569)	6.32 (1.480)	0.706
	H2c: Goal Orientation (GO)	6.24 (1.417)	6.44 (1.575)	0.338
	H2d: Self-Determination (SD)	6.20 (1.620)	6.46 (1.411)	0.227
	H2e: Self-Efficacy (SE)	6.21 (1.511)	6.43 (1.504)	0.334
	H2f: Anxiety Assessment (AA)	6.35 (1.704)	6.35 (1.473)	0.988
	H2g: Learning Interest (LI)	6.37 (1.495)	6.33 (1.523)	0.837

Table 4. Hypothesis testing for students' enjoyment using the t-test

Dependent variable	Students' enjoyment	Mean (S.D.) Low	Mean (S.D.) High	*T*
Learning Performance (LP)	H3a: Perceive Ease of Use (PEOU)	6.37 (1.504)	6.34 (1.514)	0.862
	H3b: Perceive Usefulness (PU)	6.53 (1.329)	6.19 (1.636)	0.104
	H3c: Content Design (CD)	6.35 (1.487)	6.35 (1.531)	0.983
	H3d: User Interface Design (UI)	6.31 (1.540)	6.39 (1.484)	0. 713

D. Students' Enjoyment of an Augmented Reality Inquiry-based Personalized Gaming

For students' enjoyment, there are 4 respective items, PEOU, PU, CD, and UI, to be analyzed for H3a, H3b, H3c, and H4c. The results show that the low and high groups for all items (i.e., PEOU, PU, CD, and UI) do not differ statistically in learning performance, as shown in Table 4. It means that students with low items on an enjoyment factor have equal learning achievement compared to those with high items, using the ARIPG approach.

E. Students' Acceptance of an Augmented Reality Inquiry-based Personalized Gaming

Table 5. Hypothesis testing for students' acceptance using the t-test

Dependent variable	Students' acceptance	Mean (S.D.) Low	Mean (S.D.) High	*T*
Learning Performance (LP)	H4a: Intention to Use (ITU)	6.45 (1.332)	6.28 (1.629)	0.402
	H4b: Attitude (ATT)	6.48 (1.346)	6.25 (1.613)	0.271

For students' acceptance, there are 2 items, Intention to Use (ITU) and Attitude (ATT) for H4a and H4b. Table 5 shows that the ITU and ATT have no significant differences in learning performance between the low and high groups. It means that, using the ARIPG approach, students with low scores on an acceptance factor achieve the same level of learning as those with high scores.

Furthermore, the three independent variables show the students' emotions, enjoyment, and acceptance, positively affecting their learning performance. To examine the relationships among these three factors, we used Pearson's correlation coefficient, a measure of the strength of association between variables. The results from Pearson's test confirmed a relatively strong correlation among the three factors (Table 6).

Table 6. Pearson's correlation coefficient between factors.

Factors	Emotion	Enjoyment	Acceptance
Emotion	1		
Enjoyment	0.576*	1	
Acceptance	0.602*	0.847*	1

*Correlation is significant at the 0.01 level.

VII. Discussion

This study evaluated the effectiveness of an Augmented Reality Inquiry-Based Personalized Game (ARIPG) in supporting bioscience learning among Thai undergraduate students. The results revealed that students using the ARIPG demonstrated significantly higher academic achievement than those engaged with the Conventional Personalized Game (CPG) [13]. This directly addresses the first research question, confirming that the ARIPG model provides a more effective learning experience. Moreover, the study aimed to explore how affective factors such as emotion, enjoyment, and acceptance influence academic performance, as examined through hypotheses H2, H3, and H4. These results reinforce the value of interactive, personalized digital games in enhancing subject mastery and improving student outcomes.

In examining student motivation and learning interest—categorized into high and low levels—the findings showed that both groups achieved comparable academic results. This suggests that ARIPG may help reduce disparities in learning outcomes associated with varying motivation levels. The positive effect of motivation on academic performance aligns with the self-determination theory, which emphasizes the role of intrinsic motivation in promoting effective learning [33]. Similarly, the previous study supported the notion that motivational engagement is key to educational success [34]. The findings of this study further suggest that even students with initially lower motivation can benefit from immersive learning environments such as ARIPG, thereby narrowing performance gaps among learners with diverse affective dispositions. The ARIPG diagnostic mechanism can analyze learners individually, support differentiation, and provide appropriate learning schemas. Moreover, integrating AR and inquiry-based methods helps connect students to real-world phenomena and strengthens learning in scientific inquiry, potentially reducing affective disparities among learners.

The study also explored emotional engagement and enjoyment, both of which were found to play critical roles in influencing learning outcomes. Enjoyment, in particular, showed a strong correlation with students' acceptance of the educational game (r = 0.847). In contrast, the relationship between emotion and acceptance was slightly weaker (r = 0.602), followed by the correlation between emotion and enjoyment (r = 0.576), Table 6. These findings support the finding that enjoyment significantly boosts academic performance [38]. Moreover, the study affirms the argument that learning is inherently tied to both emotion and cognition [26]. The engaging structure, game design, and interactive features of the ARIPG likely contributed to a more emotionally rewarding experience, thereby enhancing both student satisfaction and learning outcomes.

In terms of acceptance, the study found that students who exhibited low and high levels of acceptance toward ARIPG acquired the same amount of knowledge effectively. This supports earlier findings that no significant link between acceptance and learning performance [34]. However, in this study, acceptance emerged as a pivotal factor not only affecting how students interact with the game but also influencing the emotional and enjoyment dimensions. By reducing the performance gap between students with varying affective responses, the ARIPG demonstrated the potential to support more equitable learning experiences. Ultimately, the study concluded that the ARIPG represents a successful educational game model that enhances performance while addressing differences in motivation, emotion, enjoyment, and acceptance, thereby improving overall learning effectiveness.

A. *Theoretical and Practical Implications*

This study contributes by developing an original augmented reality inquiry-based personalized game that advances digital educational game design and deepens understanding of how individual emotional differences impact learning performance. Furthermore, the proposed personalized educational game environment represents progress in addressing individual conceptual learning challenges and enhancing experiential visualization through augmented reality and simulation technologies. This foundation paves the way for future research to explore the effects of educational simulation games, integrated with scientific inquiry and cutting-edge technologies such as cloud computing, artificial intelligence, and wearable devices, on learning outcomes and technology acceptance within science education.

B. *Limitation*

While this study offers valuable insights into students' learning performance and attitudes toward educational games, it also has some limitations. First, although it presents compelling quantitative results demonstrating the impact of learning performance and its relationship with factors such as emotion, enjoyment, and acceptance through the proposed educational games, further incorporating behavioral, qualitative, and in-depth analysis—such as interviews or content analysis of student behavior—would provide additional understanding for future studies. Second, the game development was limited to a specific set of technology tools. Expanding the design and development to support a wider range of technologies and platforms would be beneficial. Third, the learning achievement assessment, with 10 multiple-choice items, might not capture all dimensions of conceptual understanding. Conducting more assessment tests would improve the effects of testing. Fourth, although the multiple-choice test was validated and covered all targeted concepts, it may not fully capture higher-order conceptual understanding or students' reasoning processes in complex bioscience learning. Moreover, the use of identical items in the pre-test and post-test may have introduced testing effects, as some students could have remembered specific items or answer options. Future studies should consider incorporating parallel test forms, open-ended questions, or performance-based assessments to provide a more comprehensive evaluation of learning outcomes.

VIII. Conclusions

This study developed an ARIPG approach to the bioscience topic of DNA translation and transcription for undergraduate students in Thailand. The experimental group learned through the ARIPG approach, while the control group learned through the CPG approach. The experimental analysis showed that the ARIPG approach yielded greater learning gains than the CPG approach. Regarding students' individual affective factors, emotions, enjoyment, and acceptance were studied and found not to affect learning performance and to be positively related to students' learning performance toward the proposed educational game. Consequently, there are correlations among the affection factors. Furthermore, the proposed educational game approach could reduce students' gaps (i.e., emotion, enjoyment, and acceptance) to improve their learning outcomes. More importantly, it shows that the proposed educational game could improve the students' learning performance. The learning content and game interface designs (in terms of students' enjoyment) could reduce students' affective differences and lead to positive relationships with learning performance. These well-structured game designs could support students' emotions, enjoyment, and acceptance, leading to effective learning. However, this study mainly reviewed a quantitative analysis. Researchers in this field would gain greater insights if a follow-up study were conducted employing a qualitative approach that includes additional individual factors and explores various game platforms or designs.

Ethics Approval

Granted exemption by the Mahidol University Center of Ethical Reinforcement for Research COE No. MU-MOU 2022/019.0402 on 4th February 2022, and compliance with ethical standards.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

N.K. performed the literature search and data analysis. N.K. wrote the first draft of the manuscript, and P.P. commented on previous versions. All authors read and approved the final manuscript.

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References

[1] P. Chaipidech, N. Srisawasdi, T. Kajornmanee, and K. Chaipah, "A personalized learning system-supported professional training model for teachers' TPACK development," *Computers and Education: Artificial Intelligence*, vol. 3, 100064, 2022.

[2] H. Xie, H. C. Chu, G. J. Hwang, and C. C. Wang, "Trends and development in technology enhanced adaptive/personalized learning: A systematic review of journal publications from 2007 to 2017," *Computers and Education*, vol. 140, 103599, 2019.

[3] T. Ingkavara, P. Panjaburee, N. Srisawasdi, and S. Sajjapanroj, "The use of a personalized learning approach to implementing self-regulated online learning," *Computers and Education: Artificial Intelligence*, vol. 3, 100086, 2022.

[4] M. C. Sáiz-Manzanares, R. Marticorena-Sánchez, and C. I. García-Osorio, "Monitoring students at the university: Design and application of a Moodle plugin," *Applied Sciences*, vol. 10, no. 10, 3469, 2020. doi: https://doi.org/10.3390/app10103469

[5] N. Komalawardhana and P. Panjaburee, "Proposal of personalised mobile game from inquiry-based learning activities perspective: Relationships among genders, learning styles, perceptions, and learning interest," *International Journal of Mobile Learning and Organisation*, vol. 12, no. 1, pp. 55–76, 2018.

[6] C. Wongwatkit and P. Panjaburee, "A duplex adaptation mechanism in the personalized learning environment," *Journal of Computers in Education*, vol. 11, no. 4, pp. 1111–1131, 2024.

[7] D. Tsybulsky, "Digital curation for promoting personalized learning: A study of secondary-school science students' learning experiences," *Journal of Research on Technology in Education*, vol. 52, no. 3, pp. 429–440, 2020.

[8] P.-Y. Yin, K.-H. Chuang, and G.-J. Hwang, "Developing a context-aware ubiquitous learning system based on a hyper-heuristic approach by taking real-world constraints into account," *Universal Access in the Information Society*, vol. 15, no. 3, pp. 315–328, 2016.

[9] H. Alamri, V. Lowell, W. Watson, and S. L. Watson, "Using personalized learning as an instructional approach to motivate learners in online higher education: Learner self-determination and intrinsic motivation," *Journal of Research on Technology in Education*, vol. 52, no. 3, pp. 322–352, 2020.

[10] P. Panjaburee, G.-J. Hwang, U. Intarakamhang, N. Srisawasdi, and P. Chaipidech, "Effects of a personalized game on students' outcomes and visual attention during digital citizenship learning," *Cogent Education*, vol. 11, no. 1, 2351275, 2024.

[11] C.-A. Schoenenberger, S. Korkut, J. Jaeger, and R. Dornberger, "BioTourney: Gamifying a biology class by applying a content-independent learning game framework," in *Proc. European Conference on Games-Based Learning*, 2016, pp. 575–583.

[12] J. DeMink-Carthew and S. Netcoh, "Mixed feelings about choice: Exploring variation in middle school student experiences with making choices in a personalized learning project," *RMLE Online*, vol. 42, no. 10, pp. 1–20, 2019.

[13] N. Komalawardhana, P. Panjaburee, and N. Srisawasdi, "A mobile game-based learning system with personalised conceptual level and mastery learning approach to promoting students' learning perceptions and achievements," *International Journal of Mobile Learning and Organisation*, vol. 15, no. 1, pp. 29–49, 2021.

[14] J. Thanyaphongphat and P. Panjaburee, "Effects of a personalized ubiquitous learning support system based on learning style-preferred technology type decision model on university students' SQL learning performance," *International Journal of Mobile Learning and Organisation*, vol. 13, no. 3, pp. 233–254, 2019.

[15] M. Fang, O. Tapalova, N. Zhiyenbayeva, and S. Kozlovskaya, "Impact of digital game-based learning on the social competence and behavior of preschoolers," *Education and Information Technologies*, vol. 27, no. 3, pp. 3065–3078, 2022.

[16] M. Y. Yi and Y. Hwang, "Predicting the use of web-based information systems: Self-efficacy, enjoyment, learning goal orientation, and the technology acceptance model," *International Journal of Human-Computer Studies*, vol. 59, no. 4, pp. 431–449, 2003.

[17] D. J. Ketelhut and C. C. Schifter, "Teachers and game-based learning: improving understanding of how to increase efficacy of adoption," *Computers & Education*, vol. 56, pp. 539–546, 2011.

[18] C. Wongwatkit, P. Panjaburee, and N. Srisawasdi, "A proposal to develop a guided-inquiry mobile learning with a mastery learning mechanism for improving students' learning performance and attitudes in Physics," *International Journal of Mobile Learning and Organisation*, vol. 11, no. 1, pp. 63–86, 2017.

[19] P. Panjaburee, N. Komalawardhana, and T. Ingkavara, "Acceptance of personalized e-learning systems: A case study of concept-effect relationship approach on science, technology, and mathematics

courses," *Journal of Computers in Education*, vol. 9, pp. 681–705, 2022.

[20] K. R. Bujak, I. Radu, R. Catrambone, B. MacIntyre, R. Zheng, and G. Golubski, "A psychological perspective on augmented reality in the mathematics classroom," *Computers and Education*, vol. 68, pp. 536–544, 2013. doi: 10.1016/j.compedu.2013.02.017

[21] I. Radu, J. Yuan, X. Huang, and B. Schneider, "Charting opportunities and guidelines for augmented reality in makerspaces through prototyping and co-design research," *Computers & Education: X Reality*, vol. 2, pp. 1–18, 2023. doi: 10.1016/j.cexr.2023.100008

[22] X. Wan, L. Shen, Z. Fang, S. Dong, S. Zhang, and C. Lin, "A novel motionless calibration method for augmented reality surgery navigation system based on optical tracker," *Heliyon*, vol. 8, no. 12, pp. 1–9, 2022. doi: 10.1016/j.heliyon.2022.e12115

[23] W. Tarng, Y.-J. Lin, and K.-L. Ou, "A virtual experiment for learning the principle of daniell cell based on augmented reality," *Applied Sciences (Switzerland)*, vol. 11, no. 2, 762, pp. 1–24, 2021.

[24] U. Dorji, P. Panjaburee, and N. Srisawasdi, "Gender differences in students' learning achievements and awareness through residence energy saving game-based inquiry playing," *Journal of Computers in Education*, vol. 2, no. 2, pp. 227–243, 2015.

[25] N. Srisawasdi and P. Panjaburee, "Implementation of game-transformed inquiry-based learning to promote the understanding of and motivation to learn chemistry," *Journal of Science Education and Technology*, vol. 28, no. 2, pp. 152–164, 2019.

[26] B. Brezovszky, J. McMullen, K. Veermans, M. M. Hannual-Sormunen, G. Rodriguez-Aflecht, N. Pongsakdi, E. Laakkonen, and E. Lehtinen, "Effects of a mathematics game-based learning environment on primary school students' adaptive number knowledge," *Computers and Education*, vol. 128, pp. 63–74, 2019.

[27] Michail N. Giannakos, "Enjoy and learn with educational games: Examining factors affecting learning performance," *Computers & Education,* vol. 68, pp. 429-439, 2013.

[28] N. H. Frijda, *The Emotions*, Cambridge, NY: Cambridge University Press, 1986.

[29] R. Pekrun, T. Goetz, W. Titz, and R. Perry, "Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research," *Educational Psychologist*, vol. 37, pp. 91–105, 2002.

[30] M. Alavi and D. E. Leidner, "Research commentary: Technology-mediated learning—a call for greater depth and breadth of research," *Information Systems Research*, vol. 12, no. 1, pp. 1–10, 2001.

[31] S.-Y. Hung, K.-L. Huang, and W.-J. Yu, "An empirical study of the effectiveness of multimedia disclosure of informed consent: A technology mediated learning perspective," *Information & Management*, vol. 48, no. 4–5, pp. 135–144, 2011.

[32] S.-W. Chou and C.-H. Liu, "Learning effectiveness in a web-based virtual learning environment: A learner control perspective," *Journal of Computer Assisted Learning*, vol. 21, no. 1, pp. 65–76, 2005.

[33] S. M. Glynn and T. R. Koballa, Jr., "Motivation to learn college science," in *Handbook of College Science Teaching*, J. J. Mintzes and W. H. Leonard, Eds. 2006, pp. 25–32.

[34] M. K. O. Lee, C. M. K. Cheung, and Z. Chen, "Acceptance of Internet-based learning medium: The role of extrinsic and intrinsic motivation," *Information & Management*, vol. 42, no. 8, pp. 1095–1104, 2005. doi: 10.1016/j.im.2003.10.007

[35] R. M. Ryan and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being," *American Psychologist*, vol. 55, no. 1, pp. 68–78, 2000.

[36] A. Antonio, N. Martin, and A. Stagg, "Engaging higher education students via digital curation," in *Proc. Ascilite*, 2012.

[37] R. Hay, "Exploring the relationship between emotions and the acquisition of computer knowledge," *Computers and Education*, vol. 50, no. 4, pp. 1269–1283, 2008.

[38] J. C. Hong, M. Y. Hwang, S. Y. E. Szeto, C. R. Tsai, Y. C. Kuo, and W. Y. Hsu, "Internet cognitive failure relevant to self-efficacy, learning interest, and satisfaction with social media learning," *Computers in Human Behavior*, vol. 55, pp. 214–222, 2016.

[39] P. Tarasak and N. Komalawardhana, "Augmented reality enhanced board games in educational research: a systematic review," *International Journal of Mobile Learning and Organisation*, vol. 20, no. 1, pp. 24–58, 2026.

[40] D. W. Putwain, S. Becker, W. Symes, and R. Pekrun, "Reciprocal relations between students' academic enjoyment, boredom, and achievement over time," *Learning and Instruction*, vol. 54, pp. 73–81, 2018.

[41] V. Venkatesh, C. Speier, and M. G. Morris, "User acceptance enablers in individual decision making about technology: toward an integrated model," *Decision Sciences*, vol. 33, pp. 297–316, 2002.

[42] V. Venkatesh, "Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model," *Information Systems Research*, vol. 11, pp. 342–365, 2000.

[43] F. D. Davis, "User acceptance of information technology: System characteristics, user perceptions and behavioral impacts," *International Journal of Man–Machine Studies*, vol. 38, pp. 475–487, 1993.

[44] F.-C. Ou Yang, H.-M. Lai, and Y.-W. Wang, "Effect of augmented reality-based virtual educational robotics on programming students' enjoyment of learning, computational thinking skills, and academic achievement," *Computers & Education*, vol. 195, 2023.

[45] C.-M. Chao, "Factors determining the behavioral intention to use mobile learning: An application and extension of the UTAUT model," *Frontiers in Psychology*, vol. 10, 2019. doi: 10.3389/fpsyg.2019.01652

[46] Y.-Y. Tsai, C.-M. Chao, H.-M. Lin, and B.-W. Cheng, "Nursing staff intentions to continuously use a blended e-learning system from an integrative perspective," *Quality & Quantity*, vol. 52, no. 6, pp. 2495–2513, 2018. doi: 10.1007/s11135-017-0540-5

[47] R. Pekrun, "The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice," *Educational Psychology Review*, vol. 18, no. 4, pp. 315–341, 2006.

[48] F. Abdullah, R. Ward, and E. Ahmed, "Investigating the influence of the most commonly used external variables of TAM on students' Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) of e-portfolios," *Computers in Human Behavior*, vol. 63, pp. 75–90, 2016.

[49] C. L. Hsu and H. P. Lu, "Why do people play online games? An extended TAM with social influences and flow experience," *Information & Management*, vol. 41, no. 7, pp. 853–868, 2004.

[50] I. Ha, Y. Yoon, and M. Choi, "Determinants of adoption of mobile games under mobile broadband wireless access environment," *Information & Management*, vol. 44, no. 3, pp. 276–286, 2007.

[51] C. Wongwatkit, N. Srisawasdi, G. J. Hwang, and P. Panjaburee, "Influence of an integrated learning diagnosis and formative assessment-based personalized web learning approach on students learning performances and perceptions," *Interactive Learning Environments*, vol. 25, no. 7, pp. 889–903, 2017.

[52] J. Bourgonjon, M. Valcke, R. Soetaert, and T. Schellens, "Students' perceptions about the use of video games in education," *Computers & Education*, vol. 54, no. 4, pp. 1145–1156, 2010.

[53] S. Dawson, L. Heathcote, and G. Poole, "Harnessing ICT potential: The adoption and analysis of ICT systems for enhancing the student learning experience," *International Journal of Educational Management*, vol. 24, no. 2, pp. 116–128, 2010.

[54] L. A. Zadeh, "Fuzzy sets," *Information and Control*, vol. 8, no. 3, pp. 338–353, 1965.

[55] T. Teo, "Modelling technology acceptance in education: A study of pre-service teachers," *Computers & Education*, vol. 52, no. 2, pp. 302–312, 2009. doi: 10.1016/j.compedu.2008.08.006

[56] N. Komalawardhana and P. Panjaburee, "The incorporation of inquiry-based learning into digital game: A pilot study on gender and learning style differences in students' perceptions," in *Proc. 24th International Conference on Computers in Education*, Asia-Pacific Society for Computers in Education, India, 2016.

[57] P. Panjaburee and N. Srisawasdi, "An integrated learning styles and scientific investigation-based personalized web approach: A result on conceptual learning achievements and perceptions of high school students," *Journal of Computers in Education*, 2016. doi: 10.1007/s40692-016-0066-1

[58] G. J. Hwang and H. F. Chang, "A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students," *Computers & Education*, vol. 56, no. 4, pp. 1023–1031, 2011.