A Preliminary Evaluation of Secondary School Students' Acceptance Toward Augmented Reality Learning Materials in Genetics

Khwuanchira Chamnankul, Khon Kaen University, Thailand
Phattaraporn Pondee, Khon Kaen University, Thailand
Niwat Srisawasdi, Khon Kaen University, Thailand

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Abstract
Research literature on augmented reality (AR) in science learning suggests high technology acceptance, citing its immersive nature that enhances students' engagement and understanding. Studies highlighted AR's ability to merge abstract scientific concepts with tangible experiences and to foster positive attitudes and increased acceptance among learners towards technology-infused education. This study aimed to develop an AR mobile application to visualize biological concepts of genetics and then evaluate students' acceptance toward the AR app. This study engaged 47 ninth-grade students from the Northeastern region of Thailand to examine their acceptance of the AR app. It emphasized an interconnection among macroscopic, microscopic, and symbolic representations. Employing pre-experimental research of one-group posttest-only design, they independently interacted with the genetic AR app for 70 minutes, and then a 20-item 5-point Likert scale questionnaire was administered at the end of the session for 10 minutes. The results found that students positively perceived the genetic AR app measuring in four key dimensions: perceived usefulness (PU), perceived ease of use (PEU), attitude toward using (ATT), and behavioral intention to use (BI). The positive acceptance of the AR app suggested its potential as an effective tool for enhancing genetics education, meriting its integration into science curricula to improve learning outcomes.

Keywords: Technology Acceptance, Augmented Reality, Genetics Education, Secondary School Students

1. Introduction

Rapid technological changes are affecting the pattern of teaching and learning. In addition, technology-enhanced learning is becoming more popular and increasing in research and development for school science (Srisawasdi & Panjaburee, 2015). One such technology is Augmented Reality (AR), which interweaves the real world with a virtual world, presenting graphics, video, image 3D, and animation through mobile devices (Chookaew et al., 2017). The extensive use of AR in education is because it is a technology that capable of interacting with a wide range of learning styles and functions seamlessly on various platforms, such as tablets, smartphones, and notebooks. Furthermore, improving efficiency of AR captivates students' interest and motivates them to learn science. AR enriches the understanding of abstract concepts and strengthens the efficiency of science learning management (Irwanto et al., 2022).

Understanding genetics can pose challenges for students due to the need to assimilate abstract and intricate concepts and master particular terminology (Knippels, 2002). The abstract nature of genetics results in a decline in learners' motivation if they are not in contexts that connect genetics to their daily lives or relevant personal and societal issues (Knippels et al., 2005). Some studies addressed this challenge by designing and testing new teaching and learning activities using the integral technology into science education. (Arslan, 2020). Deep et al. (2020) created Genetics Investigation (GI), a web-based learning environment to support the gradual development of complex understanding in Mendelian genetics. The findings indicated significant improvement in learning following the integration with GI and learners' perceptions that the activities within GI are beneficial for understanding concepts and engaging in inquiry practices. In addition, Arslan et al. (2020) developed a mobile AR for biology. The aim was to enhance students' comprehension of critical and complex topics within the domains of biology, anatomy, physiology, and experimental animals. The findings found that students increased their learning motivation and enhanced their academic achievement in biology. Moreover, Diki et al. (2022) created an AR application to help students understand the DNA replication process. AR enables students to visualize tangible objects. An advantage of applying AR is its capability to facilitate the observation of DNA components integral to the replication process. Hence, previous studies indicated that technology could visualize and simplify complex content. Furthermore, AR can inspire learning motivation.

Consequently, this study aims to develop an augmented reality to encourage students' acceptance of genetic material AR applications in secondary school to address the research question on how students accept using augmented reality after participating in augmented reality activities about genetic material.

2. Literature Review

2.1 Augmented Reality

Augmented reality (AR) is a technology that combines the real and virtual worlds by placing virtual elements in real-world settings to create interactive experiences (Azuma, 1997). It is an application and technology of computer-generated 3D images complemented by audio, video, graphics, and location (GPS) data (Bistaman et al., 2018). Moreover, AR is visible through digital devices such as digital glasses, tablets, smartphones, or other visual display devices (Lertbumrungchai, 2020), and can facilitate interactive learning experiences, improve knowledge retention and transfer, and enhance students' engagement (Wang et al., 2017). It combines the real and virtual worlds (Chookaew et al., 2017), facilitating the understanding of complex or abstract ideas (Arici et al., 2019). Furthermore, AR dramatically enhances students' motivation, helps them understand abstract content and complex concepts, and fosters a positive attitude toward learning (Weng et al., 2019). Recently, there are four types of AR technology: marker-based AR, markerless AR, projection-based AR, and superimposition-based AR (Filali & Krit, 2019). The study by Yilmaz (2021) utilized marker-based AR, allowing users to interact through mobile devices. The AR process began by employing smartphone apps to scan marked objects and symbols on all prepared items. Once the software system identified and stored the specific symbols on the surface, it proceeded to process the objects, rendering them as 3D images on the smartphone screen.

2.2 Augmented Reality in Science Education

In the contemporary era, internet technologies have revolutionized our daily lives and are regarded as promising tools for enhancing education in the 21st century (Salmi et al., 2017). So, teachers should provide technology-based instructional materials and design learning environments that align with learners' interests and needs are vital aspects to enable them to engage in active learning and gain hands-on experience throughout their science subject. Science subjects often contain numerous abstract concepts that require changing abstract in a concrete form and visualization of these abstract terms to align with learners' perception levels. Therefore, utilizing AR technology in science education can be an encouraging solution to address the challenges posed by abstract and complex science content concepts because integrating AR technology into science affects learners' more precise insights into science-related information (Xu et al., 2022). In previous studies, many researchers provided results that applying AR technology in science education. For example, Costa et al. (2021) developed the Planetary System GO MAR AR game that, as a location-based AR game, focuses on the celestial bodies and planetary systems of the universe to model the Solar System. This AR fosters interactive learning and promotes a deeper understanding of cosmic phenomena. Besides, Ciloglu & Ustun (2023) implemented mobile AR-based biology learning to increase students' motivation, self-efficacy, and attitude toward biology. The findings revealed that students who engaged in biology learning through mobile AR showed significantly higher self-efficacy levels than those who followed traditional methods. However, no notable distinctions between the experimental and control group students regarding motivations and attitudes toward biology learning were observed. Including the study by Diki et al. (2022), which focuses on creating an AR application to aid students in understanding the DNA replication process more effectively. These findings also indicated that mobile AR applications were innovative, non-disruptive, effective for knowledge acquisition, engaging, fascinating, and enjoyable and found to enhance the retention of information, provide a tangible grasp of the subject matter, and ease the learning process.

2.3 Technology Acceptance Model (TAM)

The technology acceptance model (TAM) is used to determine how people view or accept technology (Davis & Venkatesh, 1996) and as an effective behavioral model (Davis, 1985). The TAM model finds application in various research projects centered around new technologies. To explain users' acceptance of novel information systems in computer technology (Oktavendi & Mu'ammal, 2022). According to studies, the elements affected to accept the various technologies of disciplines and users' acceptance. In the previous studied, Kusonyang et al. (2023) investigated Thai context of the AR acceptance for primary school students on electric circuits used four issues to consider users' acceptance as Perceived Usefulness (PU), Perceived Ease of Use (PEU), Attitudes (ATT), and Behavior Intention (BI). The details of each issue are as follows: Perceived usefulness (PU) refers to how individuals perceive the usefulness of information technology systems. Perceived ease of use (PEU) refers to perceived ease of use as defined as the extent to which individuals perceive how user-friendly information technology systems are. Attitude toward using (ATT) pertains to users' positive or negative perceptions of the learning experience with the information technology system, and Behavior Intention to use (BI) refers to the frequency of users using the information technology learning system in the future (Hua Lo al., 2021). Also, in previous studies, several researchers studied the effects of users' acceptance of technology.

Hua Lo et al. (2021) examined the technology acceptance model results in science education. They developed an augmented reality on the ecosystem to enhance students' learning about plants. The findings found that it correlated with higher intentions to use the application among students who exhibited more positive attitudes towards its usage. Furthermore, Panjaburee et al. (2022) studied students' acceptance of personalized e-learning systems. The findings indicated their attitudes and behavioral intentions to use the personalized e-learning system. Personalized e-learning was influenced by their perceived ease of use and usefulness.

Moreover, these factors contributed to the student's perception of the learning guidance the personalized e-learning systems generated as applicable. In addition, Kusonyang et al. (2023) studied students' acceptance of AR on the series circuits. The results discovered that students have a high behavioral intention to use AR in learning. They tend to have high perceived usefulness, ease of use, and enjoyment in AR-based learning, thus demonstrating a relatively high behavioral intention to use AR.

3. Research Methodology

3.1 Participants

The participants were 47 ninth-grade students at the secondary school in the Northeast of Thailand. There were 30 females (63.83%) and 17 males (36.17%). Their ages ranged from 14 to 16 years old, which consisted of 30 individuals aged 14 (63.83%), 16 individuals being 15 years (34.04%), and one individual being 16 years (2.13%). They had not yet experienced using Augmented Reality applications in the context of science learning before.

3.2 Mobile Augmented Reality on Genetics Materials

The study was the development an instructional augmented reality application called “Genetic Material AR.” Figure 1A shows the initial screen app, including scan AR, contact developer (Facebook, website), and how to. The users can interact with both Android and iOS. According to the literature review, it proposed that the development of AR applications should consider five key design elements, including information, interface, interaction, imagination, and immersion (Masmuzidin et al., 2022). There were three sub-issues regarding *information design*: (1) physical content design, which these elements suggested to design with the curriculum. Hence, this AR emphasized on two learning standards and indicators of the national primary education curriculum: (1.1) Explain the relationship between genes, DNA, and chromosomes using a model, and (1.2) Explain how alterations in genes or chromosomes can lead to the development of genetic disorders and provide instances of such conditions; (2) Virtual content design that refers to multimedia elements such as text, image, audio, video, and animation. Therefore, this AR app comprised text for content explanation and 3D objects; and (3) Marker design that provided image makers. *Interface design*, this issue advises separating into three areas: the display area, main button area, and description area. Accordingly, the AR Genetic Material was categorized into three areas. The display area represented 3D models that appear in the center position of the screen immediately after scanning. The AR Genetic Material app contained various buttons for functions like 'Home,' which facilitated users in returning to the initial screen, 'Capture,' Utilized to capture screenshots; and 'Quiz,' to assess understanding following the study of 3D images, over and above that the AR Genetic Material app provided a description area on the left or right side of the 3D models. The users could get more information about those 3D models, as shown in Figure 1B.

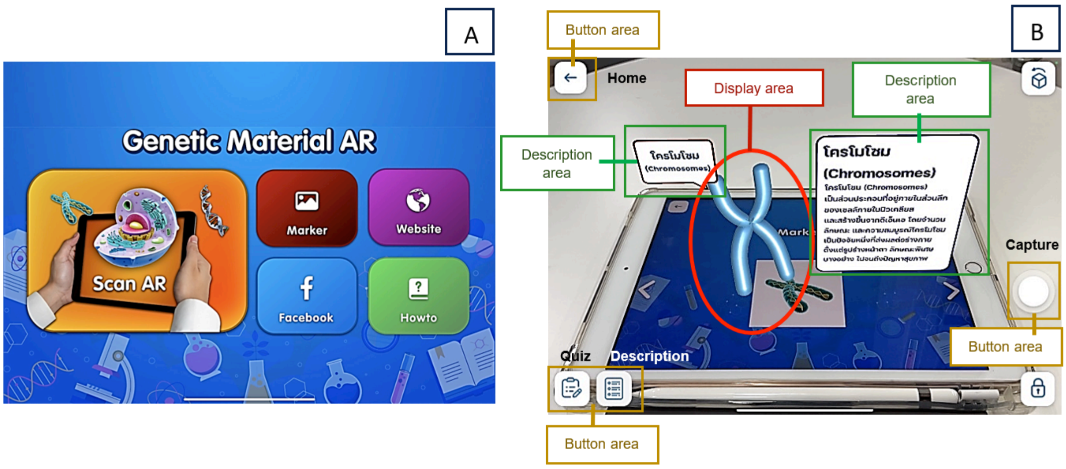

Figure 1: An example screenshot from Genetic Material AR:
A) the initial screen, B) the interface design.

Additionally, the Genetic Material AR followed three levels of representation in biological phenomena: macroscopic, microscopic, and symbolic level. The principle above represented the levels of biological phenomena is consistent with Marbach-Ad & Stavy (2000), which aligned with the suggestions: (1) the macroscopic level, where biological structures are observable to the naked eye, (2) the cellular or subcellular (microscopic) level, where structures become visible only under the light or electron microscopes, (3) the molecular (submicroscopic) level, encompassing DNA, proteins, and diverse biochemicals and (4) the symbolic level offers explanatory methods for phenomena expressed through symbols, equations, chemical formulas, metabolic routes, numerical computations, genotypes, patterns of inheritance, and similar concepts. At macroscopic level referred to visualizing external features; this app created a scenario to engage students to observe the outer structure of the zebra about a banding of two zebras. This marker illustrated how to express zebra's individual characteristics to link an organism's hereditary characteristics. Students scanned through an image-based marker, and then this AR app detected and displayed 3D models, as shown in Figure 2A.

Further, the microscopic level could only be observed under a microscope. Genetic material relates to an organism's components inside an animal cell composed of chromosomes, DNA, and genes. Consequently, this AR app was built to display those components from unobservable to be visualized. The users scanned image-based markers, and 3D objects appeared, as shown in Figure 2B. In addition, structures and types of chromosomes were at the microscopic level. In this matter, markers were designed with unique features, each of which must be touched. If paired correctly, it will detect and display the 3D model as shown in Figure 2C, and the symbolic level offered explanatory mechanisms for phenomena symbolized by the DNA's base pair structure. The users needed to align the markers of the base pairs by touching them together, and when all four markers were correctly aligned, the AR application would detect and showcased the 3D model, as shown in Figure 2D.

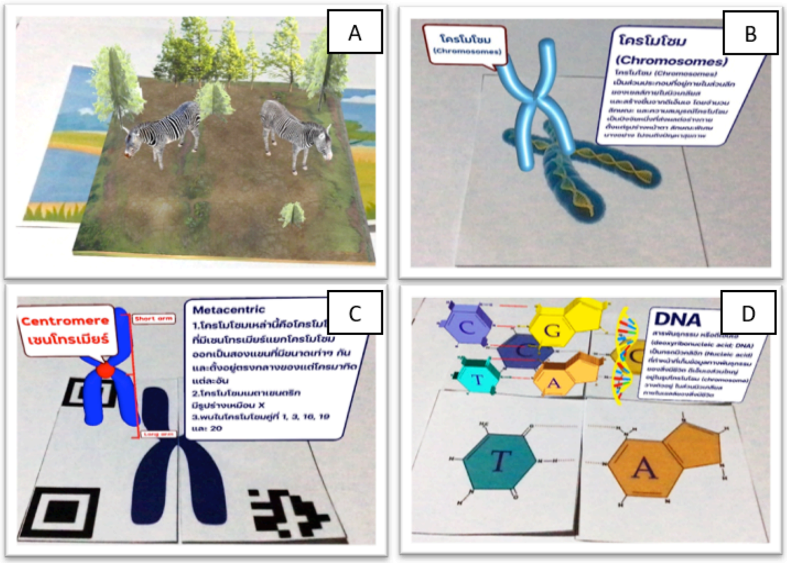

Figure 2: An example screenshot from Genetic Material AR illustrating:
(A) Hereditary characteristics, (B) Structure of chromosomes,
Types and structure of chromosomes, (D) Base pairs of DNA.

3.3 Data Collection

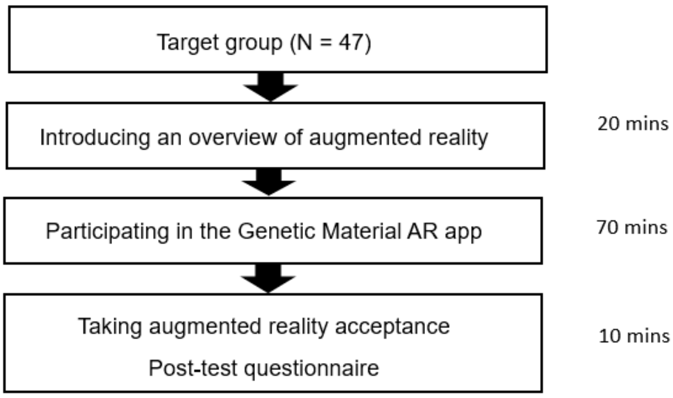

Figure 3: Experimental designs.

This research used a pre-experimental design to conduct one group post-test only design, as shown in Figure 3. A mobile augmented reality was built to develop the genetic material for 9-th grade students. The first author introduced an augmented reality app to participants before interacting for 20 minutes. Then they were assigned to interact with AR through five tasks: (1) observing the zebra streak to clarify differences in the external features between two zebras, (2) solving the puzzle of zebra streaks to link hereditary characteristics, (3) explaining the relationship between genes, DNA, and chromosomes, (4) descripting the inner structure of DNA, and (5) explanation of types of chromosomes. After participating in the augmented reality application, the participants expressed opinions on augmented reality acceptance through a 5-point Likert scale questionnaire for 10 minutes. The questionnaire focused on the augmented reality acceptance model, to evaluate how the participants perceived the AR. The evaluation included acceptable, reliable, and valid, divided into four dimensions: 1. Perceived Usefulness (PU), 2. Perceived Ease of Use (PEU), 3. Attitudes (ATT), and 4. Behavior Intention (BI), adopted from previous research (Kusonyang et al., 2023; Hua Lo et al., 2021). This instrument consisted of 15 items using a Likert scale ranging from 1 to 5: Strongly disagree = 1, Disagree = 2, Neither agree/ disagree = 3, Agree = 4, and Strongly agree = 5. Descriptive statistics were used to analyze data consisted of mean and standard deviation.

3.4 Data Analysis

This study validates the reliability of the augmented reality acceptance questionnaire by using Cronbach's alpha. In addition, the four dimensions of augmented reality acceptance were analyzed by applying mean and standard deviation.

4. Results and Discussion

The results in Table 1 illustrate the students' acceptance of augmented reality in four dimensions: PU, PEU, ATT, and BI. The overall mean scores of all four dimensions indicated that the mean scores ranged from 4.39 (for attitudes and behavior intention) to 4.50 (for perceived ease of use). These findings specified that the students positively accepted augmented reality in all dimensions, and Cronbach's alpha reliability was above 0.70 for four issues of acceptance.

Table 1. Descriptive data of students' acceptance toward utilizing augmented reality

Dimensions	N	Mean	S.D.	Cronbach Alpha (>.07)
Perceived Usefulness (PU)	47	4.45	0.78	0.89
Perceived Ease of Use (PEU)	47	4.50	0.88	0.74
Attitudes (ATT)	47	4.39	0.83	0.89
Behavior Intention (BI)	47	4.39	0.75	0.76

The findings found that "perceived ease of use" is the highest acceptance because the "Genetic Material AR" is designed based on the principle of AR development for children. This rationale supports students in learning more simply. Furthermore, the app covers two operating systems (iOS and Android) and can easily be downloaded.

In this study, AR learning applications were designed and developed for genetics materials to engage, motivate, and visually represent this content for 9-th grade students. There were various features, for instance, 3D objects and dynamic visuals. The findings correlated with the study of Hua Lo et al. (2021), which developed AR-based learning activities for natural science inquiry. The results indicated that students could gain knowledge about the natural world using AR apps. Furthermore, these apps offered touchable sensations by incorporating videos, special effects, and augmented reality elements, and students demonstrated their favorable reception of using augmented reality for science education. Further, according to Kusonyang et al. (2023), the results of developed mobile augmented reality of series circuits for science learning. The findings found that students had positive views of using augmented reality overall four dimensions: PU, PEU, ATT, and BI.

Conclusions

This research was an AR design and development of learning applications on genetic material to engage secondary school students. This application is compatible with both Android and iOS operating systems. The genetic material AR app is a marker-based augmented reality that uses two types of markers: QR code markers and image-based markers. The application feature involves presenting 3D objects alongside detailed scientific explanations. Consequently, students interacting with the AR app displayed eagerness for hands-on learning participation. Moreover, the students exhibited favorable perspectives regarding the acceptance of augmented reality.

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Contact email: Khwuanchira.c@kkumail.com