Online-Journals.org

iJIM International Journal of Interactive Mobile Technologies

iJIM | eISSN: 1865-7923 | Vol. 18 No. 7 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijim.v18i07.42261

PAPER

The Development of Problem-Based Mobile Augmented Reality Application to Enhance Creative Problem-Solving Skills for Undergraduate Students

Piyanoot Wongklang(✉), Jirasak Wipatsopakron

Faculty of Education, Nakhon Ratchasima Rajabhat University, Nakhon Ratchasima, Thailand

piyanoot.w@nrru.ac.th

ABSTRACT

This study aims to develop a problem-based mobile augmented reality (AR) application to enhance creative problem-solving skills among undergraduate students. The research involves an experiment conducted on a sample group of 30 undergraduate students enrolled in the maintenance of computers and audio-visual equipment course, selected through a simple random sampling method. The instruments used in the study included structured interview questions, needs assessment questionnaires, quality evaluation of mobile applications, evaluation of the learning plan, measurement of creative problem-solving ability, and satisfaction surveys. The data obtained were analyzed using mean, standard deviation, dependent t-test, and effect size statistics. The findings demonstrated that the developed mobile application achieved the highest quality level, with an average value of 4.62 (SD = 0.64). The mobile application efficiency reached 75.48 out of 75.16, meeting the established threshold of 75 out of 75. Using the mobile application led to statistically significant improvements in creative problem-solving skills after the learning process, with scores higher than those before learning at the 0.05 level. The effect size was 6.61, indicating a large impact. Additionally, student satisfaction with the mobile application was reported as the highest.

KEYWORDS

mobile application, augmented reality (AR), problem–based, creative problem-solving skills

1 INTRODUCTION

Higher education institutions play a crucial role in producing high-quality graduates equipped with practical competencies and skills to effectively perform real-world tasks. However, there are some issues with the quality of Thai graduates. Most graduates still lack the practical skills required by the labor market. New graduates are unable to apply their knowledge practically in their jobs. When graduates encounter

Wongklang, P., Wipatsopakron, J. (2024). The Development of Problem-Based Mobile Augmented Reality Application to Enhance Creative Problem-Solving Skills for Undergraduate Students. *International Journal of Interactive Mobile Technologies (iJIM)*, 18(7), pp. 53–67. https://doi.org/10.3991/ijim.v18i07.42261

Article submitted 2023-06-13. Revision uploaded 2024-02-03. Final acceptance 2024-02-03.

problems at work, they struggle to resolve their situations. They are too indecisive to make a decision. They do not devise new solutions for their problems [1, 2]. Therefore, educational institutions need to find ways to produce graduates who meet the requirements of society. Creative problem-solving skills are essential in the labor market. If graduates have creative problem-solving skills, they will be able to think critically and synthesize issues to use information effectively in problem-solving. They will demonstrate creativity in determining solutions for unknown and diverse problems and then the most appropriate method to solve work-related problems or apply the solutions to various situations in their daily lives [3, 4]. For these reasons, educational institutions must urgently find ways to encourage graduates' creative problem-solving skills so that they are fully equipped and competitive when entering the labor market.

Organizing learning activities for undergraduate students classified as Generation Z, who grew up with technological advancements, enables this group to learn more effectively through technology. They are particularly adept at learning with mobile devices such as smartphones and tablets, which allow them to access information anywhere and anytime, making learning more flexible. Mobile devices also create new opportunities for collaboration, participation, and personal learning. This provides an opportunity for students to create their own body of knowledge independently and to be more engaged in the learning process [5, 6]. Therefore, students should be encouraged to learn using mobile devices and modern technologies. AR is another technology that is becoming more popular day by day. AR technology is designed to integrate AR objects with real-world objects on the display [7, 8], enabling us to deliver complex content or provide a clearer display of internally structured content. For the advancement of education in Thailand through the use of AR technology, it has been observed that students are more satisfied with mobile applications that incorporate AR technology across various subject areas. It also helps increase student interest and attraction and can explain any difficult-to-understand or abstract concepts in a more concrete manner [9]. Lee also mentioned that AR plays a role in enhancing students' understanding. The instructors' presentation of content helps make instruction effective, creates a conducive learning atmosphere, and enables students' interaction during learning, effectively stimulating students' interest [10].

Combining learning strategies with the usability of AR technology will enhance the effectiveness of learning. According to research studies, problem-based learning management has been found to equip students with effective skills for creative problem-solving. This is because problem-based instruction is derived from using problems from real-life situations that students may encounter [11, 12], emphasizing student participation. This learning process will make students eager to learn, enthusiastic, and capable of finding solutions to various problems from diverse sources. The problems encountered should necessitate analytical thinking to engage in the systematic problem-solving process and determine the most effective method for solving various problems [13, 14]. With the properties of AR technology, content can be presented in a concrete way. This enables students to preview actual working problem situations through simulation scenarios, providing them with experiences very similar to those they will encounter in real life. Students can practice solving problems in various scenarios [15] and train themselves repeatedly until they gain confidence. These can enhance students' skills to solve problems creatively [16]. Due to the significance and challenges outlined above, the researcher believes that developing a mobile application with AR technology using problem-based methods to enhance creative problem-solving skills in undergraduate students will improve their ability to address issues creatively. This approach aims to elevate the quality of education by leveraging technology to cultivate graduates with skills that align with the demands of the 21st century job market. These graduates will possess the

necessary capabilities to thrive in competitive environments and navigate rapid changes effectively.

2 LITERATURE REVIEW

2.1 Augmented reality

Learning with technology helps make learning more efficient. Students can access information anywhere and anytime, resulting in more flexible learning. This allows students to create a body of knowledge independently and become more engaged in the learning process [6, 17]. AR technology is utilized in mobile devices, such as smartphones and tablets, to display the overlap and interaction between the real and virtual worlds [18]. This technology enables students to enjoy learning and visualize real images or events related to the content. The virtual images that appear will immediately interact with the user in the form of both 3D images and animations. AR technology can present complex content in a more tangible manner [19], which can engage students and facilitate easy access to the mobile application, leading to an improvement in learning outcomes [20]. Many researchers study the use of AR in instructional design. For example, El Sayed et al. [21] utilized AR to deliver lessons in 3D format. AR can present objects in various forms and is interactive. Learning utilizes high-performance technology that aids in the development of learning skills and academic achievement, ultimately enhancing learning efficiency. Sahin and Yilmaz [22] also discovered that AR contributed to enhancing student achievement. The students had positive attitudes towards learning and preferred to study using AR. The students did not show any signs of anxiety when using AR. Furthermore, a positive relationship was found between academic achievement and students' attitudes. AR can be used in conjunction with problem-based learning activities. This helps students immerse themselves in learning activities through audio, video, 3D simulations, etc., enabling them to visualize concepts in a virtual environment. Villarán et al. [23] and Astuti et al. [24] also found that AR influences the development of problem-solving skills, stimulates motivation, and helps enhance learning outcomes for students.

2.2 Problem-based learning

Problem-based learning (PBL) is a learning approach that aims to provide students with hands-on experiences. It is a student-centered approach where students actively participate in learning, engage in problem-solving, practice critical thinking skills, and confront challenging situations. PBL helps to foster motivation in students' learning. With challenging workloads, it promotes good thinking and problem-solving skills. Learning with PBL uses problems to enhance students' intelligence [13, 25]. PBL is a teaching approach that focuses on resolving authentic real-world problems. It is a dynamic process that requires students to take responsibility for their own learning [26, 27].

Problem-based learning encourages students to develop the ability to clearly define learning problems, identify and analyze various challenges, seek explanations for the causes and reasons behind the problems, and then summarize the data as principles and guidelines for problem-solving. There are study results that utilize PBL and AR for organizing instruction. It was found that students who used AR technology in the PBL process achieved significantly higher academic scores compared to those who used only PBL or traditional one-teacher, one-classroom instruction. This is consistent with the results of Fidan et al. [28] and Garzón et al. [29],

which indicate that AR technology improves student learning skills. PBL can enhance higher-order thinking skills. Students can criticize and think analytically so that they can solve problems in real life. It also leads to a significant difference in the higher-order thinking skills of students before and after learning.

2.3 Skills in creative problem-solving

Skills in creative problem-solving involve the use of higher-order thinking skills, incorporating creativity, critical thinking, and problem-solving to address issues in an innovative manner [30]. Students are required to seek various and innovative answers to solve problems in limited situations. They should then be able to choose the appropriate solution, explain each step of the problem-solving process reasonably, and articulate the impact of selecting methods to solve problems until it leads to effective problem-solving action planning [31, 32]. Five steps are synthesized from Guilford [31], D'Zurilla and Goldfried [33], and Mitchell and Kowalik [34] by the researcher as follows:

1. **Identifying the problem.** This is an important part that serves as the starting point for solving problems. The solver of the problem must identify the issue and its underlying causes.
2. **Finding methods to solve the problem.** This stage involves expressing creativity by exploring numerous ways to solve the problem without passing judgment on their correctness and generating new ideas for potential solutions.
3. **Selection of methods to solve problems.** It involves evaluating the optimal approach to solving the problem, taking into account both the supports and obstacles that may arise during the problem-solving process.
4. **Planning for problem-solving.** Problem-solving is the process of planning to address issues by utilizing the skills and limitations of individuals, context, conditions, and various resources used for solving problems.
5. **Action.** Put the plans into practice. Supervise and follow up on problem-solving. Compare the results or goals that have been set.

3 RESEARCH METHODS

3.1 Research objectives

To develop and study the results of using a mobile AR application through problem-based methods to enhance creative problem-solving skills.

3.2 Research hypothesis

After using a problem-based mobile AR application, students exhibit higher creative problem-solving skills compared to those who did not use the application, with statistical significance at the .05 level.

3.3 Participants

1. There are a total of five experts. All of the experts have the following qualifications: they have earned a doctoral degree; they are experts in mobile AR applications,

problem-based learning, and creative problem-solving; and they either have at least three years of teaching experience or have conducted academic work in these fields.

2. The sample in the mobile AR application performance testing consisted of 32 third-year undergraduate students from the Faculty of Education's Computer Studies Department. They were divided into three stages: individual testing with three students, small group testing with nine students, and field tryouts with 20 students.
3. The sample in the mobile AR application experiment consisted of 30 third-year undergraduate students from the Faculty of Education's Computer Studies Department.

3.4 Content used in the research

The content used in this study focuses on the maintenance of computers and audiovisual equipment. It consists of three chapters: 1) The principles of basic maintenance; 2) Problem analysis and equipment maintenance; and 3) Security in maintenance.

3.5 Research instruments

Each of the research instruments was validated by five experts using the index of item objective congruence (IOC) criteria with an acceptable level of 0.5 [35]. The instruments used in the research are described in Table 1.

Table 1. Research instruments

Research Instruments	Characteristics of the Instruments
Structured interview questions	The questions included aspects related to the design and development of problem-based mobile AR application for learning, the characteristics of mobile application in promoting creative problem-solving skills, and additional advice. The obtained IOC index ranged from 0.60–1.00.
Needs assessment questionnaire	The questionnaire comprised three parts. Part 1 was general information about respondents in a checklist format. Part 2 was about conditions and requirements for developing the learning environment model, utilizing a dual response format. Part 3 included open-ended questions for additional suggestions. The IOC index obtained ranged from 0.60–1.00.
Quality evaluation of mobile application	The quality evaluation of mobile application was divided into 3 parts. Part 1 assessed content quality. Part 2 was the assessment of mobile application quality, and additional suggestions were solicited through open-ended responses. The assessment employed a 5-level rating scale: 4.50–5.00 (highest), 3.50–4.49 (high), 2.50–3.49 (moderate), 1.50–2.49 (low), and 1.00–1.49 (lowest). The IOC index obtained ranged from 0.60–1.00.
Evaluation of learning plan	The learning plan evaluation was divided into 3 parts. Part 1 evaluated content quality. Part 2 was the evaluation of mobile application quality. The additional suggestions were open-ended responses. The evaluation used a 5-level rating scale: 4.50–5.00 (highest), 3.50–4.49 (high), 2.50–3.49 (moderate), 1.50–2.49 (low), and 1.00–1.49 (lowest). The IOC obtained was between 0.60 and 1.00.
Measurement of creative problem-solving skills	The measurement of creative problem-solving skills comprised five written situational questions covering five areas of creative problem-solving skills: problem identification, finding solutions, selecting methods to solve problems, planning to solve problems, and taking action. The IOC obtained was between 0.60 and 1.00. The reliability of the test, calculated using Cronbach's alpha coefficient, was found to be 0.83.
Satisfaction survey questionnaire	The satisfaction survey questionnaire consisted of three parts. Part 1 evaluated content quality. Part 2 was about the evaluation of mobile application quality. The additional suggestions were open-ended responses. The evaluation utilized a five-level rating scale: 4.50–5.00 (highest), 3.50–4.49 (high), 2.50–3.49 (moderate), 1.50–2.49 (low), and 1.00–1.49 (lowest). The IOC obtained was between 0.60 and 1.00.

3.6 Methodology

The research methodology is divided into three steps: 1. Preliminary stage, 2. development stage, and 3. Testing phase. There are steps as shown in Figure 1.

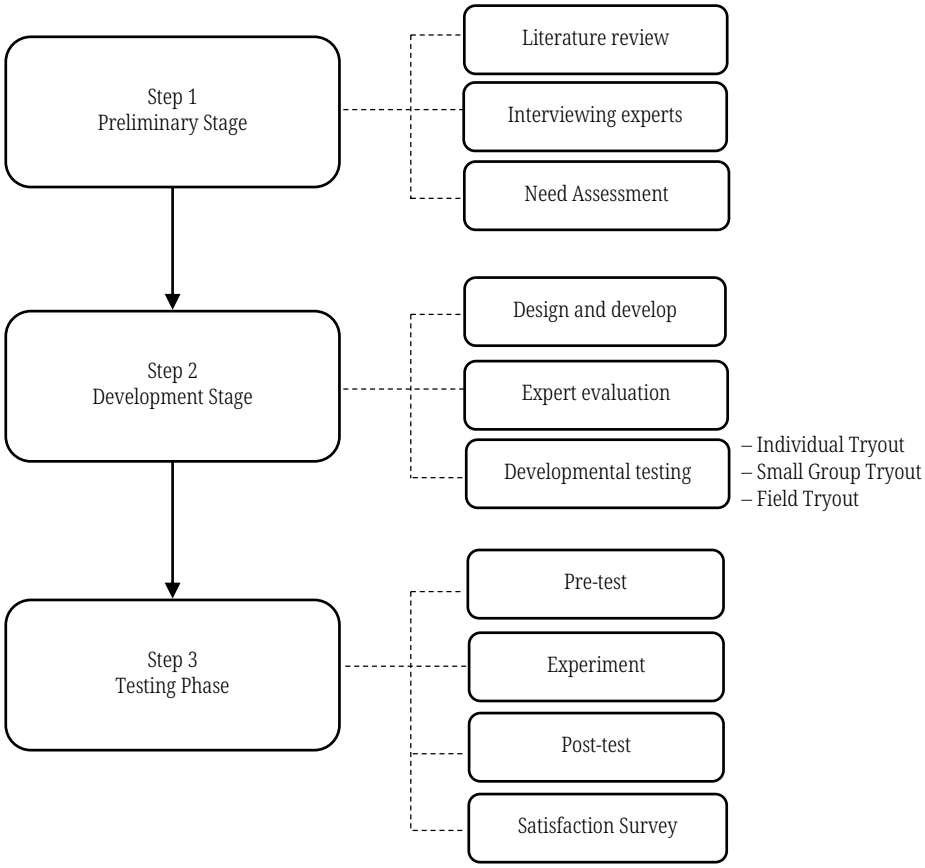

Fig. 1. Scheme of research and development (R&D) method

The details of each step can be described as follows:

Step 1: The preliminary stage begins with a literature review, followed by interviews with five experts. The interview issue pertains to guidelines for mobile application development. Next, utilize all the findings obtained from the interviews to conduct a content analysis and gather the opinions of 266 students regarding the current learning environment and the necessity of using a mobile AR application. Finally, analyze the findings derived from the students' opinions using the modified priority needs index (PNI Modified).

Step 2: The development stage involves using the findings obtained from Step 1 to design and develop the mobile application. Additionally, create a draft of a storyboard and transform it into a mobile AR application using Vidinoti applications. Bring the developed mobile application to five experts for evaluation of its quality and to receive suggestions. The researcher enhanced and adjusted the mobile application and conducted developmental testing with 32 students who had varying academic abilities, following Phromwong's stages, starting with an individual tryout. Tested with three students in;

(2) Group developmental tryout. Tested with nine students; (3) Field developmental tryout with twenty students [36]. During the tryout process, the students' behaviors were observed, and inquiries were made about potential improvements. In each of the tryout stages, the data was analyzed for efficiency, which was configured as follows: E1 = efficiency of process, and E2 = efficiency of product. The efficiency threshold was set to E1/E2 75/75.

Step 3: Testing phase. The students are requested to complete the assessment of creative problem-solving skills before learning, and the testing has been conducted for eight consecutive weeks. After the students complete their learning process, which involves various steps, they are required to take an assessment to evaluate their creative problem-solving skills post-learning. Then, the students are required to complete a survey for their mobile application satisfaction levels. In the end, the assessment findings were utilized for data analysis using SPSS for Windows version 28.

4 RESULTS

4.1 Results of the development of problem-based mobile augmented reality application to enhance creative problem-solving skills

1. The results of the interviews with experts regarding approaches to developing AR mobile applications revealed that such applications should possess the following attributes: content that aligns with practical context; compatibility with various mobile operating systems; system stability; easily accessible menus; animated images; inclusion of challenging problem scenarios or missions to motivate students to solve problems; integration of content with daily and professional life; consideration of individual differences; scaffolding provide to support students who struggle to complete missions; and provision of additional learning resources for independent student learning.

   According to the results of a survey on viewpoints regarding the current conditions and needs of using mobile AR applications, it was found that students' top priority is the need to apply acquired knowledge to solve various work-related situations. The second priority is the need for a mobile application that can help users easily comprehend any content and demonstrate engaging mobile application usage to support learning. Thirdly, there is a need for mobile applications that are visually engaging and realistic.
2. The results of the evaluation of mobile application quality by the experts show that the average score is 4.62 (SD = 0.64). The content quality is found to be at a good level ($\bar{x}$ = 4.51, S.D. = 0.45). When considering each of the dimensions, the top three aspects that gained the highest quality included consistency between contents and objectives, which was at a very high level ($\bar{x}$ = 4.75, S.D. = 0.43), followed by usefulness, up-to-date, accuracy, and easy-to-understand, which was at a very highly rated ($\bar{x}$ = 4.63, S.D. = 0.48), and content correctness, which was at a high level ($\bar{x}$ = 4.50, S.D. = 0.50).

   The mobile application design quality is also found to be at a good level ($\bar{x}$ = 4.49, S.D. = 0.43). When considering each dimension, the top three aspects that received the highest quality ratings were a deeper understanding of the content, which scored very high ($\bar{x}$ = 5.00, S.D. = 0.00), followed by claruty and appeal of contents at a very high level ($\bar{x}$ = 4.75, S.D. = 0.43), and convenient

access at a very high level of clarity and appeal of the contents ($\bar{x}$ = 4.63, S.D. = 0.48).

3. The results of checking the efficiency of a mobile AR application consist of three stages. Data collection and analysis of the results are as follows:

During the individual tryout stage, it was discovered that some 3D images were not displayed throughout the tryout process. Animations were displayed very slowly. Some students did not complete their assignments within the specified time. During the small-group tryout stage, it was discovered that the letters were too small. During the use of the mobile application, the students were interested and enthusiastic about using it effectively. During the field tryout stage, it was observed that the students were enthusiastic and diligent in completing the assigned tasks within the specified time. In each stage, the assessment of the displayed performance was conducted as shown in Table 2.

Table 2. Results of efficiency tryout

Evaluation of Efficiency	n	Efficiency of the Process (E1)	Efficiency of the Result (E2)
Individual Tryout	3	70.00	73.00
Small Group Tryout	9	71.66	75.00
Field Tryout	20	75.48	75.16

According to Table 2, the study found that the problem-based mobile AR application is effective in enhancing creative problem-solving skills, with an efficiency value of 70.00/73.00. In the small group tryout stage, the efficiency score was 71.66/75.00, and in the field tryout stage, it was 75.48/75.16. The efficiency values of E1 and E2 meet the set threshold of 75/75, which can be used in organizing instruction. The developed mobile AR application contains the following components: 1) A marker, which is used to locate an object's position, can be viewed through physical objects such as computers and audio-visual equipment and can display the position on a paper-based knowledge sheet. 2) Mission menu for problem situations 3) Scaffolding menu 4) Learning resources menu, as previewed in Figures 2–4.

Fig. 2. A preview of examining the objects that determine the marker position reveals a 3D image

Fig. 3. Preview of a knowledge sheet where students can scan images or QR codes to log into the menu

Fig. 4. Picture depicting the mission menu scene with a sample of a problem situation

4.2 The result of using mobile AR application

1. The comparative results for creative problem-solving before and after learning with a mobile AR application is shown in Table 3.

Table 3. Comparative results of creative problem-solving among the sample group before and after learning with mobile AR application

	Total Score	Before Studying		After Studying		Mean Difference (95%CI)		p-Value†	Effect Sizes (d)‡ (95%CI)	
		M	SD	M	SD					
Total score	35	16.68	1.46	28.45	2.05	11.78	(10.86 – 12.69)	<0.001*	6.61	(4.79 – 8.43)

Notes: Abbreviations: M, Mean; SD, Standard deviation; CI, confidence interval. †P-value corresponds to the Wilcoxon signed-rank test; ‡Effect sizes (Cohen's d) were calculated by the sample standard deviation of the mean difference; *Significant at p-value < 0.05.

From Table 3, the average score for creative problem-solving before studying was 16.68, while the average score for creative problem-solving after studying increased to 28.45 on average. Hence, the students achieved higher scores in creative problem-solving after studying compared to before studying, with statistical significance at the .05 level (p-value < 0.001) and a large effect size (d = 6.61).

Table 4. Comparative results of creative problem-solving among the sample group before and after learning with mobile augmented reality application (itemized)

Itemized	Total Score	Before Studying		After Studying		Mean Difference (95%CI)		p-Value†	Effect Sizes (d)‡ (95%CI)	
		M	SD	M	SD					
1. Identifying the problem	7	3.59	0.46	5.15	0.56	1.56	(1.29 – 1.82)	<0.001*	3.04	(1.99 – 4.07)
2. Finding methods to solve the problem	7	3.08	0.51	5.85	0.44	2.77	(2.52 – 3.01)	<0.001*	5.82	(4.18 – 7.45)
3. Selection of methods-to-solve-problems	7	3.35	0.63	5.77	0.47	2.42	(2.13 – 2.70)	<0.001*	4.35	(3.04 – 5.67)
4. Planning for problem solving	7	3.25	0.69	5.97	0.75	2.72	(2.34 – 3.09)	<0.001*	3.78	(2.58 – 4.97)
5. Action	7	3.40	0.52	5.71	0.41	2.32	(2.08 – 2.56)	<0.001*	4.93	(3.49 – 06.37)

Notes: Abbreviations: M, Mean; SD, Standard deviation; CI, confidence interval; †P-value corresponds to the Wilcoxon signed-rank test; ‡Effect sizes (Cohen's d) were calculated by the sample standard deviation of the mean difference. *Significant at p-value < 0.05.

From Table 4, the students significantly improved in all five skills after studying the mobile AR application. The skill that showed the largest gain was "Skills in Finding Methods to Solve Problems," with an effect size of 5.82, followed by "Action skill" (4.93), and "Selection of Methods to Solve-Problems" (4.35).

2. The results of student satisfaction with the mobile AR application showed that satisfaction was at the highest level ($\bar{x}$ = 4.55, S.D. = 0.49). When considering each of the dimensions, the top three aspects that gained the highest quality included up-to-date learning content, which was at a very high level ($\bar{x}$ = 4.73, S.D. = 0.44), followed by interesting techniques used in the presentation, which was at a very high level ($\bar{x}$ = 4.66, SD = 0.49) and self-studying. The content was rated as very high level ($\bar{x}$ = 4.61, SD = 0.49).

5 DISCUSSION

The development of a problem-based mobile AR application to enhance creative problem-solving skills has been systematically undertaken. A literature review and a research review are conducted. In addition, experts' opinions are sought to explore ways to develop mobile applications, and students' needs are also investigated. This study reveals that the average score for mobile application quality evaluation by experts is 4.62 (SD = 0.64). The developed mobile AR application utilizes content related to the maintenance of computers and audio-visual equipment. The content of this course should enable students to understand the internal structures of the equipment and the troubleshooting steps for each piece of equipment. The students are also required to be able to solve problems in any situation. The AR app can help students see 3D images of structures. The images can be rotated 360 degrees,

allowing students to realistically visualize the structure from all angles. Also, it allows students to clearly see visualize the animated positions and working processes of various devices, enabling them to understand the concrete processes. Based on our observation, students are highly interested in mobile applications and find the presentation of content through video clips of real-life problem situations during task performance helpful. This approach enables students to visualize methods and approaches to problem-solving.

In the mission section, which is the assignment for the students to solve problems, it helps create challenges, allowing students to address issues, complete assigned activities, and practice problem-solving. The students can practice repeatedly until they become proficient and confident in solving problems. This section aligns with Chaimongkhol et al.'s research, which indicates that AR apps help students clearly visualize the steps of practice, aiding in the comprehension of instructions and operational methods [37]. Students can learn more at any time they need, which can lead to improved grades.

For the scaffolding and learning resource menus, these menus provide assistance in cases where some students may have difficulty finding the answer while completing the assigned mission. According to observations during testing, students frequently utilize the scaffolding menu to aid in problem-solving in Mission 1, which involves investigating the cause of the problem. That may be because the students are not confident yet in their ability to accurately identify the problem. This is in line with the research of Raes et al. [38], which applies the scaffolding theory to online learning. It provides examples and suggestions that help students find answers successfully, or it adds more tools for interacting with teachers through chat boxes or question-and-answer programs. Scaffolding will help students feel more at ease when learning independently. The Learning Resource menu will help students access information on various guidelines to solve problems, enabling them to make the most appropriate solution choice. Therefore, providing scaffolding and learning resource menus for students is essential in developing a mobile application that enhances self-learning and problem-solving skills.

As for the testing of the effectiveness of the mobile AR application, it was found to have an efficiency rating of 75.48/75.16, which meets the established threshold of 75/75 because the researcher tested the developed mobile application before implementing it with the samples. During testing, flaws and errors in the mobile application, as well as students' behaviors, are revealed. Subsequently, corrections and improvements are implemented, resulting in an efficient mobile application that meets the established threshold. This is in line with the research concepts of Promwong [39] and Sodajun et al. [40]. Chaiyong indicated that media performance testing allows manufacturers to ensure that the content contained in the media is appropriate, easy to understand, and an effective and ready-to-use prototype. Similarly, Suparat developed an interactive mobile application with AR technology. She discovered that the media had an efficiency of 77.92/75, which met the specified criteria of 75/75. This is because AR was enhanced and modified following procedures to assess the performance of the mobile application until it evolved into a tool that facilitated easy and enjoyable learning, leading to more effective lessons.

The study findings reveal that utilizing a problem-based mobile AR application to improve creative problem-solving skills led to higher scores among students after learning compared to scores before learning. With statistical significance at the .05 level. This outcome aligns with the initial hypothesis, and the mobile application demonstrated a substantial effect size (d = 17.92) on the problem-solving

skills score. This may be because the AR mobile application is interesting and easy for students to understand, It allows users to realistically visualize processes and steps using AR technology. By incorporating real-world problem situations, it stimulates awareness of the challenges that arise in work settings. Thus, it piques students' interest in solving problems and completing the assigned missions. The students have the skills to use menus to assist them in actively seeking answers and learning more. As a result, the AR app can promote students' creative problem-solving skills. These findings are consistent with Fidan and Tuncel [41], who suggested that when students effectively manage and create an initial plan to solve problems, starting from problem identification to searching for solutions, it helps them recognize, comprehend, and address their own problems. This involves creating a plan to systematically solve the problems, enabling students to utilize all of their available skills to address the challenges.

The results of the study on students' satisfaction with learning using a mobile AR application reveal that students are highly satisfied. This is because the mobile AR application has been designed to cater to students' memory retention needs, resulting in an application that effectively meets students' requirements. The students are interested in and impressed with using modern technology actively for learning. The mobile application is easy to understand, featuring beautiful and realistic animated images. It simplifies complex content for easier comprehension and is user-friendly and convenient to use. The students can also review the lesson content by themselves at any time and anywhere, which leads to the highest level of satisfaction. This is in line with the concept of Khan et al. [42], who discovered that AR technology is an intriguing innovation. It also helps to illustrate the details of what you want to convey without using actual items. When applied to teaching, it piques students' interest and enables them to easily access the mobile application, leading to improved learning efficiency.

6 CONCLUSION

Problem-based mobile AR applications excellently promote students' creative problem-solving skills, resulting in higher levels of creativity after learning. AR applications also have a significant impact on enhancing creative problem-solving skills. This influence leads to a systematic approach to developing AR apps, incorporating experts' opinions, and addressing students' needs, ultimately resulting in high-quality AR applications. Furthermore, the AR app is tested for efficiency to ensure it meets the requirements and threshold-based performance. Mobile AR applications use problem situations that occur in work settings to create simulation scenarios for students. This allows them to see problems that are as similar to reality as possible and to complete missions to solve the problems. Students can practice solving problems from the assigned missions as many times as they need to gain confidence in solving the problems. Using an AR app allows students to visualize 3D structures and understand the working process clearly. As a result, students develop the skills to solve problems creatively and are highly satisfied with their learning through mobile AR applications. This is because the mobile application can adapt to students' needs, is user-friendly, and offers convenience. Moreover, students are impressed with the use of modern technology in learning through problem-based mobile AR applications. For these reasons, the skills of creative problem-solving are enhanced efficiently [37, 38, 39, 40, 41, 42].

7 ACKNOWLEDGEMENT

This research study was supported by Nakhon Ratchasima Rajabhat University, Thailand.

8 REFERENCES

[1] D. Schreuder and M. Coetzee, *Careers an Organisational Perspective*. Claremont: Juta Limited, 2011.

[2] World Economic Forum, "The future of jobs report 2020," 2020. [Online]. Available: https://www.weforum.org/publications/the-future-of-jobs-report-2020/. [Accessed Dec. 20, 2023].

[3] A. M. Abdulla and B. Cramond, "The creative problem finding hierarchy: A suggested model for understanding problem finding," *Creativity. Theories – Research – Applications*, vol. 5, no. 2, pp. 197–229, 2018. https://doi.org/10.1515/ctra-2018-0019

[4] M. K. Foster, "Design thinking: A creative approach to problem solving," *Management Teaching Review*, vol. 6, no. 2, pp. 123–140, 2021. https://doi.org/10.1177/2379298119871468

[5] S. Kattayat, S. Josey, and A. J. V, "Mobile learning apps in instruction and students achievement," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 11, no. 1, p. 143, 2017. https://doi.org/10.3991/ijim.v11i1.6420

[6] St. Papadakis, "Choosing the best educational apps for young children: What parents and educators need to know," *Desafíos de la inclusión digital: la brecha digital de género y las competencias digitales docentes en el contexto educativo*, pp. 77–94, 2023.

[7] N. Sazen, "Samaritans and saffron interactive, samaritans veterans app: Case study for the effective use of mobile learning to deliver learning, development and wellbeing management skills," *Int. J. Adv. Corp. Learn.*, vol. 15, no. 2, pp. 57–64, 2022. https://doi.org/10.3991/ijac.v15i2.34133

[8] F. Arena, M. Collotta, G. Pau, and F. Termine, "An overview of augmented reality," *Computers*, vol. 11, no. 2, p. 28, 2022. https://doi.org/10.3390/computers11020028

[9] S. S. Ali, "Problem based learning: A student-centered approach," *English Language Teaching*, vol. 12, no. 5, p. 73, 2019. https://doi.org/10.5539/elt.v12n5p73

[10] K. Lee, "Augmented reality in education and training," *TechTrends*, vol. 56, no. 2, pp. 13–21, 2012. https://doi.org/10.1007/s11528-012-0559-3

[11] H. S. Barrows and R. M. Tamblyn, *Problem-Based Learning: An Approach to Medical Education*, vol. 1, New York: Springer Publishing Company, 1980.

[12] A. Walker, H. Leary, and C. Hmelo-Silver, (Eds.), *Essential Readings in Problem-Based Learning: Exploring and Extending the Legacy of Howard S. Barrows*. Indiana: Purdue University Press, 2015. https://doi.org/10.2307/j.ctt6wq6fh

[13] J. R. Savery, "Overview of problem-based learning: Definitions and distinctions," *Interdisciplinary Journal of Problem-Based Learning*, vol. 1, no. 1, pp. 5–15, 2006. https://doi.org/10.7771/1541-5015.1002

[14] A. B. D. Silva, A. C. K. D. A. Bispo, D. G. Rodriguez, and F. I. F. Vasquez, "Problem-based learning: A proposal for structuring PBL and its implications for learning among students in an undergraduate management degree program," *Revista de Gestão*, vol. 25, no. 2, pp. 160–177, 2008. https://doi.org/10.1108/REGE-03-2018-030

[15] W. Li, A. Nee, and S. Ong, "A state-of-the-art review of augmented reality in engineering analysis and simulation," *Multimodal Technologies and Interaction*, vol. 1, no. 3, p. 17, 2017. https://doi.org/10.3390/mti1030017

[16] O. O. Lavrentieva, I. O. Arkhypov, O. I. Kuchma, and A. D. Uchitel, *Use of Simulators Together with Virtual and Augmented Reality in the System of Welders' Vocational Training: Past, Present, and Future*, 2020. https://doi.org/10.31812/123456789/3748

[17] S. Kattayat, S. Josey, and A. J. V., "Mobile learning apps in instruction and students achievement," *International Journal of Interactive Mobile Technologies*, vol. 11, no. 1, pp. 143–147, 2017. https://doi.org/10.3991/ijim.v11i1.6420

[18] B. Yang, "Virtual reality and augmented reality for immersive learning: A framework of education environment design," *Int. J. Emerg. Technol. Learn.*, vol. 18, no. 20, pp. 23–36, 2023. https://doi.org/10.3991/ijet.v18i20.44209

[19] G. Kiryakova, N. Angelova, and L. Yordanova, "The potential of augmented reality to transform education into smart education," *TEM Journal*, vol. 7, no. 3, pp. 556–565, 2018.

[20] N. F. Jeffri and D. R. Awang Rambli, "A review of augmented reality systems and their effects on mental workload and task performance," *Heliyon*, vol. 7, no. 3, 2021. https://doi.org/10.1016/j.heliyon.2021.e06277

[21] N. A. M. El Sayed, H. H. Zayed, and M. I. Sharawy, "ARSC: Augmented Reality Student Card," *Computers and Education*, vol. 56, no. 4, pp. 1045–1061, 2011. https://doi.org/10.1016/j.compedu.2010.10.019

[22] D. Sahin and R. M. Yilmaz, "The effect of augmented reality technology on middle school students' achievements and attitudes towards science education," *Computers and Education*, vol. 144, p. 103710, 2020. https://doi.org/10.1016/j.compedu.2019.103710

[23] D. Villarán, M. B. Ibáñez, and C. D. Kloos, "Augmented reality-based simulations embedded in problem based learning courses," *Design for Teaching and Learning in a Networked World*, pp. 540–543, 2015. https://doi.org/10.1007/978-3-319-24258-3_55

[24] F. N. Astuti, S. Suranto, and M. Masykuri, "Augmented reality for teaching science: Students' problem solving skill, motivation, and learning outcomes," *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 5, no. 2, pp. 305–312, 2019. https://doi.org/10.22219/jpbi.v5i2.8455

[25] T. Khemmani, *Teaching Science to Knowledge for Effective Learning Process*, 14th ed. Bangkok: Chulalongkorn University Printing House, 2011.

[26] O. S. Tan, *Problem-Based Learning Innovation: Using Problems to Power Learning in the 21st Century*. Singapore: Gale Cengage Learning, 2021.

[27] O. Díaz, E. Segredo-Morales, and E. González, "Problem-based learning. Application to a laboratory practice in the degree of industrial chemical engineering," *Int. J. Eng. Ped.*, vol. 13, no. 6, pp. 139–150, 2023. https://doi.org/10.3991/ijep.v13i6.39737

[28] M. Fidan and M. Tuncel, "Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education," *Computers and Education*, vol. 142, p. 103635, 2019. https://doi.org/10.1016/j.compedu.2019.103635

[29] J. Garzón, Kinshuk, S. Baldiris, J. Gutiérrez, and J. Pavón, "How do pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and Research Synthesis," *Educational Research Review*, vol. 31, p. 100334, 2020. https://doi.org/10.1016/j.edurev.2020.100334

[30] E. Lumsdaine and M. Lumsdaine, "Creative problem solving," *IEEE Potentials*, vol. 13, no. 5, pp. 4–9, 1995. https://doi.org/10.1109/45.464655

[31] J. P. Guilford, *The Nature of Human Intelligence*. New York: McGraw Hill, 1967.

[32] R. L. Flood and M. C. Jackson, *Creative Problem Solving: Total Systems Intervention*. New York: Springer US, 1991.

[33] T. J. D'zurilla and M. R. Goldfried, "Problem solving and behavior modification," *Journal of Abnormal Psychology*, vol. 78, no. 1, p. 107, 1971. https://doi.org/10.1037/h0031360

[34] W. E. Mitchell and T. F. Kowalik, *Reative Problem Solving*. n.p, 1999.

[35] R. J. Rovinelli and R. K. Hambleton, "On the use of content specialists in the assessment of criterion-referenced test item validity," *Tijdschrift Voor Onderwijs Research*, vol. 2, pp. 49–60, 1977.
[36] C. Phromwong, "Developmental testing of media and instructional package," *Silpakorn Educational Research Journal*, vol. 5, no. 1, pp. 7–20, 2013.
[37] N. Chaimongkol, M. A. Ungthong, and A. Sripadit, "Two important augmented reality technologies: Workpiece alignment in milling with automatic mechanical control," *Journal of Industrial Education*, vol. 19, no. 2, pp. 80–89, 2020.
[38] A. Raes, T. Schellens, B. De Wever, and E. Vanderhoven, "Scaffolding information problem solving in web-based collaborative inquiry learning," *Computers and Education*, vol. 59, no. 1, pp. 82–94, 2012. https://doi.org/10.1016/j.compedu.2011.11.010
[39] C. Phromwong, "Developmental testing of media and instructional package," *Silpakorn Educational Research Journal*, vol. 5, no. 1, pp. 7–20, 2013.
[40] S. Sodajun, T. Sovajassatakul, and S. Petsangsri, "Development of interactive learning media with augmented reality technology on home mechanics of Mathayom 4 students," *Journal of Industrial Education*, vol. 19, no. 2, pp. 30–39, 2020.
[41] M. Fidan and M. Tuncel, "Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education," *Computers and Education*, vol. 142, p. 103635, 2019. https://doi.org/10.1016/j.compedu.2019.103635
[42] T. Khan, K. Johnston, and J. Ophoff, "The impact of an augmented reality application on learning motivation of students," *Advances in Human-Computer Interaction*, vol. 2019, pp. 1–14, 2019. https://doi.org/10.1155/2019/7208494

9 AUTHORS

Piyanoot Wongklang is a Lecturer at Faculty of Education, Nakhon Ratchasima Rajabhat University. Her research interest includes Information Technology and Mobile Application (E-mail: piyanoot.w@nrru.ac.th).

Jirasak Wipatsopakron is a Lecturer at Faculty of Education, Nakhon Ratchasima Rajabhat University. His research interest includes Augmented Reality and Mobile Application (E-mail: Jirasak.w@nrru.ac.th).