

***Game-Based Learning Model Using Augmented Reality Technology
to Promote Creative Problem Solving***

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Abstract

Game-based Learning Model Using Augmented Reality Technology are educational approaches that help develop knowledge, stimulate interest and participation in learning to promote creative problem solving through an engaging and effective learning experience. The objectives of this research are: 1) To develop Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving 2) To evaluate the quality of Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving 3) To assess the satisfaction of the sample with Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving. The sample group consisted of 50 undergraduate students in the Bachelor of Science program, Applied Computer Science-Multimedia by voluntary selection method. The research tool consists of 1) Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving. 2) Quality assessment of Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving. 3) Assessment of satisfaction with Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving. The results of the research found that the overall quality of the media is at a very good level and satisfaction is at the highest level. This model not only imbues the learning process with elements of enjoyment and challenge but also underscores the cultivation of critical skills essential for adaptability across diverse situations. Moreover, it facilitates the development of innovation and creativity requisite in the face of a dynamically evolving world.

Keywords: Game-Based Learning, Augmented Reality Technology, Creative Problem Solving

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Introduction

In recent years, the landscape of education has been rapidly transforming, driven by advancements in technology and the increasing need for innovative teaching methods. Among these technological advancements, Augmented Reality (AR) has emerged as a powerful tool in educational settings, offering immersive and interactive learning experiences that can significantly enhance students' engagement and understanding. Concurrently, Game-Based Learning (GBL) has gained traction as an effective pedagogical approach, leveraging the motivational aspects of games to promote active learning and problem-solving skills. Teaching and learning via Augmented Reality technology have garnered significant attention within the educational sphere. AR integrates virtual elements with the physical world, utilizing devices like smartphones and AR glasses to overlay information and graphics onto real-world images. This technology aims to enhance learning and teaching experiences by creating immersive and value-added educational encounters, particularly beneficial in scenarios necessitating active learner engagement and enhanced communication and collaboration between educators and students.

Despite the recognized benefits of AR and GBL, there remains a gap in integrating these technologies specifically to foster creative problem-solving among students. Creative problem-solving is a crucial skill in the modern world, enabling individuals to navigate complex challenges and develop innovative solutions. However, traditional educational methods often fall short in effectively cultivating this skill, relying heavily on rote memorization and passive learning techniques. For undergraduate students in the field of computer multimedia, the challenge is twofold. Firstly, they must develop technical proficiency in multimedia tools and technologies. Secondly, they must cultivate creativity and problem-solving abilities to apply their technical skills effectively. The intersection of AR and GBL offers a promising avenue to address these educational needs, providing a dynamic and engaging platform that can simulate real-world scenarios and encourage creative thinking.

Based on the reasons, the researcher has envisioned an opportunity to impart Creative Problem Solving by presenting it through Augmented Reality Technology. By introducing a GBL model combined with AR, the concept of developing a Game-Based Learning Model Using Augmented Reality Technology to Promote Creative Problem Solving emerged. This research was inspired by the need to improve educational practices within the Computer Multimedia program and to explore the potential of AR and GBL as transformative tools in higher education. By integrating these technologies, this research aims to support the development of innovative educational strategies that not only equip students with technical skills but also foster creativity and problem-solving abilities.

Objectives

- 1) To develop Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving
- 2) To evaluate the quality of Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving
- 3) To assess the satisfaction of the sample with Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving

Literature Review

Game-Based Learning

Game-based learning represents an innovative educational strategy that harnesses the motivational elements inherent in video games to enrich learning outcomes. It involves designing educational games that optimize both enjoyment and learning (Nipo et al., 2023). Research have demonstrated that game-based learning has the potential to elevate learning proficiency across diverse domains, including logical-mathematical, naturalistic, and linguistic aptitudes (Ward, 2022). Research has particularly concentrated on assessing the efficacy of game-based learning within medical education, underscoring its comparable effectiveness to conventional instructional approaches. Additionally, it has been noted to provide heightened levels of engagement, interactivity, and enjoyment for students (Ribeiro et al., 2022). Additionally, game-based learning is recognized as a valuable tool for engaging the "Games Generations" in the workforce and educational settings, emphasizing its effectiveness across different age groups and industries (Ribeiro et al., 2022).

Augmented Reality Technology

Augmented Reality (AR) embodies an innovative technological advancement that merges virtual components with the tangible environment, consequently enhancing user experiences (Pronika et al., 2023). It enables the superimposition of virtual objects onto the physical environment, enriching interactions, and perceptions (Mujumdar, 2022). AR applications range from video games to IoT devices, offering benefits like increased security through target image verification (Phursule et al., 2023). This technology enables real-time interaction between physical and virtual entities, facilitating precise 3D placement and seamless integration of digital content into the physical environment (Permana et al., 2023). Moreover, AR finds extensive use in training scenarios, such as military operations and emergency medicine, by creating realistic simulations without the need for large-scale exercises. By combining AR with IoT, innovative solutions for controlling devices and home automation are being explored, showcasing the vast potential of this technology.

Creative Problem Solving

Creative Problem Solving (CPS) is a crucial sub-area of Artificial Intelligence (AI) that focuses on addressing off-nominal issues in autonomous systems (Gizzi et al., 2022). CPS involves problem formulation, knowledge representation, knowledge manipulation, and evaluation methods to tackle novel problems and adapt to changing environments (Lee et al., 2023). The CPS model includes fact-finding, idea-finding, and solution-finding procedures, emphasizing divergent and convergent thinking to enhance creativity and innovation (Nurrijal et al., 2023). Research highlights the similarities between problem solving and creativity, emphasizing the importance of mental processes in achieving desired outcomes (Fahrissa & Parmin, 2022). Implementing the CPS learning model has shown effectiveness in enhancing students' critical and creative thinking skills, as evidenced by experimental studies. In summary, Creative Problem Solving (CPS) significantly contributes to nurturing creativity, innovation, and adaptability across diverse domains.

Research Method

The researchers conducted the study in to 3 phases.

Phase 1: Develop Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving by studying conceptual frameworks, principles and theories from relevant documents and studies is shown in Figure 1. The process began by study and synthesis the necessary input component for the design of elements and process of game-based learning that apply to creative problem solving for learners, according to the research objective. After that the researchers use augmented reality technology as a tool to support learning management for students.

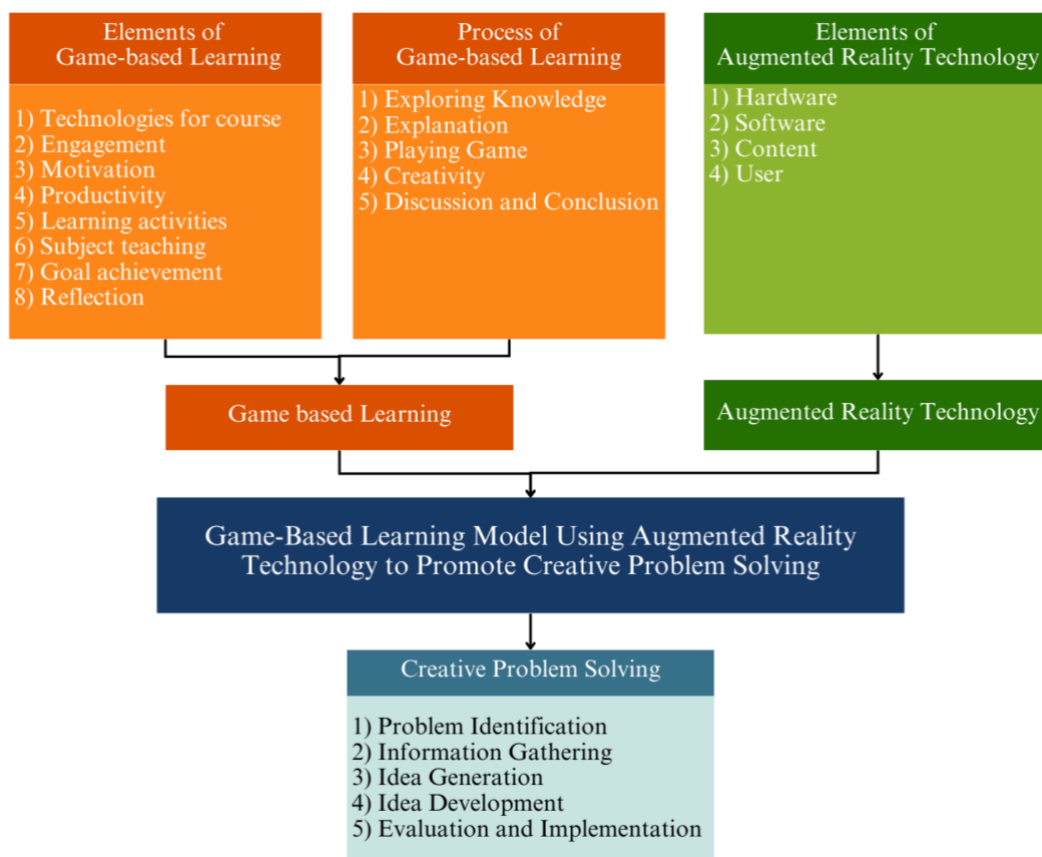


Figure 1: Conceptual Framework

The researcher develops the Game-Based Learning Model Using Augmented Reality Technology by analyzing the process synthesis of Game-Based Learning, Augmented Reality Technology, and Creative problem solving. The researchers summarize of the key process relevant and designs it as a model to show the relationships of Game-Based Learning Model Using Augmented Reality Technology (Figure 1). Such an approach facilitates individual learners in acquiring and applying creative problem-solving skills through tailored activities and processes, thereby fostering the development of abilities aligned with their specific learning objectives, goals, and potential.

Element of Game-based Learning, based on the study of Game-based Learning elements from 5 relevant documents, theories and research as detailed in Table 1.

Table 1: Synthesis of elements of Game-based Learning

Elements of Game-based Learning	Research				
	(Nipo et al., 2023)	(Ismaizam et al., 2022)	(Untari, 2022)	(Shohel et al., 2022)	(Baboo et al., 2022)
Technologies for course	/	/	/	/	/
Engagement	/	/	/	/	/
Motivation		/	/		/
Productivity	/	/		/	
Learning activities		/	/	/	/
Subject teaching	/	/	/		/
Goal achievement	/	/	/	/	
Reflection	/		/		/

From Table 1, the synthesis of summarizes the key elements of Game-based Learning consist of 8 elements, which are 1) Technologies for course 2) Engagement 3) Motivation 4) Productivity 5) Learning activities 6) Subject teaching 7) Goal achievement and 8) Reflection.

Process of Game-based Learning, based on the study of Game-based Learning process from 5 relevant documents, theories and research as detailed in Table 2.

Table 2: Synthesis of process of Game-based Learning

Process of Game-based Learning	Research				
	(Fernández-Raga et al., 2023)	(Himmawan & Juandi, 2023)	(Ribeiro et al., 2022)	(Uslu, 2022)	(Shaheen et al., 2022)
1. Exploring Knowledge	/	/		/	
2. Explanation	/		/		/
3. Playing Game	/	/	/	/	/
4. Creativity	/	/	/	/	/
5. Discussion and Conclusion	/	/	/	/	/

From Table 2, the synthesis of summarizes the key process of Game-based Learning consist of 5 processes, which are 1) Exploring Knowledge 2) Explanation 3) Playing Game 4) Creativity and 5) Discussion and Conclusion.

Phase 2: Evaluate the Quality of Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving by in-depth interviews with a detailing the steps and processes for 5 experts in education and information technologies. Utilize a 5-point Likert scale to assess the suitability of Game-Based Learning Model Using Augmented Reality Technology. Employ basic statistical methods, such as calculating the mean and standard deviation, to analyze expert evaluations.

Phase 3: Assess the satisfaction of the sample with Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving. The sample group consisted of 50 undergraduate students in the Bachelor of Science program, Applied Computer Science-Multimedia by voluntary selection method. A 5-point Likert scale is used to assess the satisfaction with the game-based learning model using Augmented Reality technology. Basic statistical methods, such as calculating the mean and standard deviation, are employed to analyze the sample group's evaluation.

Results

Model Development

Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving consist of several components. The initial element encompasses the process of Game-Based Learning, serving as the primary component of the model. It encompasses 5 primary steps: 1) Exploring Knowledge 2) Explanation 3) Playing Game 4) Creativity and 5) Discussion and Conclusion. These processes are designed to foster the attainment of learning objectives by all learners according to their individual potential. Each step further consists of sub-activities aimed at facilitating comprehensive learning experiences.

The second component is AR technology, containing AR learning environments of the online systems that can promote the Creative Problem-Solving learning process. The activities and steps can be taken AR through the online systems. There are 4 elements: 1) Hardware consists of display devices, sensors, and input devices 2) Software consists of AR platforms, development tools, learning applications 3) Content consists of 3D models, virtual content, interactive data. 4) User consists of students, teachers, developers.

The third component is Creative Problem Solving. This is a tool that drives learners to learn by themselves according to the model. It consists of 5 main elements: 1) Problem Identification 2) Information Gathering 3) Idea Generation and 4) Idea Development 5) Evaluation and Implementation. These are considered important tool that can work together to create an environment conducive to creative and effective problem solving in any situation and drive the Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving.

The 3 overarching components follow 5 steps according to the Game-based Learning process as follows.



Figure 2: Architecture of Game-Based Learning Model Using Augmented Reality Technology to Promote Creative Problem Solving

Game-Based Learning represent an intriguing educational management approach employed within the classroom setting to orchestrate learning endeavors. Game-Based Learning serves as an instructional methodology designed to invigorate student engagement in learning pursuits. Comprised of 5 sequential learning management phases 1) Exploring Knowledge 2) Explanation 3) Playing Game 4) Creativity and 5) Discussion and Conclusion, each phase contributes distinctively to the overall learning process with details as follows:

- 1) **Exploring Knowledge:** This initial phase of learning involves the teacher assessing the students' existing knowledge through a game of question and answer facilitated by digital learning tools.
- 2) **Explanation:** In the subsequent stage, the instructor introduces the game to the students and proceeds to allocate them into groups comprising 5 to 6 individuals, carefully mixed based on their proficiency levels: high, medium, and low. Following the division into groups, the teacher elucidates the game's mechanics, objectives, equipment features, and distributes corresponding worksheets to each group of learners.
- 3) **Playing Game:** In the third phase, the teacher prepares the playing area, ensuring it is conducive to gameplay. Subsequently, students engage in the game under the guidance of the teacher, who oversees adherence to the established rules. During this stage, the teacher closely monitors students' gameplay behaviors and records pertinent information conducive to their learning process. This data can be utilized for post-game discussions or assigned to certain students for observational purposes. Additionally, the teacher maintains control over the duration of gameplay.
- 4) **Creativity:** In the fourth phase, educators offer students opportunities to suggest or innovate new ideas for gameplay, such as devising novel rules aimed at enhancing enjoyment and complexity. This stage fosters an environment of creativity, encouraging the ongoing development of fresh games or activities, among other inventive endeavors.
- 5) **Discussion and Conclusion:** Step 5 represents a pivotal phase aimed at elucidating the educational impact of game-based learning to students, typically employing open-ended inquiries. The teacher initiates dialogue by posing questions designed to stimulate critical thinking. Examples include inquiries into gameplay dynamics, such as the strategies employed by winners, and the emotional responses elicited from both victors and losers. Additionally, questions pertaining to the acquisition and refinement of skills are posed, evaluating students' progress and attainment of desired objectives. Moreover, inquiries may extend to the identification of errors and strategies for improvement, or assessments of acquired knowledge through quizzes, diagrammatic representations, and summarization exercises. Subsequently, students are prompted to undertake assessments to consolidate their learning.

Results of Media Quality Assessment

The results of media quality assessment by 5 experts in the field of education and information technology are as follows:

Table 3: *The results of media quality assessment*

Item	Quality assessment level		
	X	S.D.	interpretation
Clarity of Information	4.80	0.45	very good
Accuracy and Credibility	4.60	0.55	very good
Relevance to Learning Objectives	4.20	0.84	good
Visual Presentation	4.80	0.45	very good
Interactivity	4.60	0.55	very good
Accessibility	4.60	0.55	very good
Technical Performance (AR)	4.80	0.45	very good
The duration is suitable	4.40	0.55	good
Total	4.60	0.55	very good

From Table 3, The result of overall quality of the media is at a very good level. The mean was 4.60 and the standard deviation was 0.55. When considering each topic, it was found that the topics Clarity of Information, Visual Presentation, Technical Performance (AR) had a very good level of quality. The mean was 4.80 and the standard deviation was 0.45. Topics: Accuracy and Credibility, Interactivity, Accessibility. The quality level is very good. The average is 4.60, the standard deviation is 0.55, the topic The duration is suitable has a good quality level. The topic has a mean of 4.40 and a standard deviation of 0.55. The topic Relevance to Learning Objectives has a mean of 4.20 and a standard deviation of 0.84.

Results of Satisfaction Assessment

The Assessment of satisfaction with Game-based Learning Model Using Augmented Reality Technology to promote Creative Problem Solving by 50 undergraduate students in the Bachelor of Science program, Applied Computer Science-Multimedia by voluntary selection method are as follows:

Table 4: *The results of satisfaction assessment of students*

Item	Satisfaction assessment level		
	X	S.D.	interpretation
The presentation of the content is engaging	4.60	0.76	highest
The content maintains consistent relevance and clarity	4.58	0.78	highest
The picture clarity is suitable	4.44	1.05	high
The character designs are aesthetically pleasing and appropriate	4.52	0.79	highest
The duration is suitable	4.44	0.81	high
The visual composition is aesthetically pleasing	4.80	0.45	highest
The font style and size are clear and appropriate	4.52	0.79	highest
The presentation of the media is intriguing	4.44	0.81	high
The media has the potential to motivate the audience	4.60	0.61	highest
The media encourages viewers to contemplate creative problem-solving	4.76	0.59	highest
Total	4.57	0.76	highest

From Table 4, The result of overall satisfaction is at the highest level with an overall mean of 4.57 and a standard deviation of 0.76. When considering each topic, it was found that the topic The visual composition is aesthetically pleasing had a very high level of satisfaction. has a mean of 4.80 and a standard deviation of 0.45. Topic: The media encourages viewers to contemplate creative problem-solving. There is a very high level of satisfaction. The average was 4.76 and the standard deviation was 0.59. The topic the media has the potential to motivate the audience had a very high level of satisfaction. The mean was 4.60 and the standard deviation was 0.61. The topic the presentation of the content is engaging had a very high level of satisfaction. The average was 4.60 and the standard deviation was 0.76. The content maintains consistent relevance and clarity had a very high level of satisfaction. The mean was 4.58 and the standard deviation was 0.78. The topic the character designs are aesthetically pleasing and appropriate, the font style and size are clear and appropriate had a very high level of satisfaction. The average was 4.52 and the standard deviation was 0.79. The topic the duration is suitable, the presentation of the media is interesting had a high level of satisfaction. has a mean of 4.44 and a standard deviation of 0.81. The topic the picture clarity is suitable has a high level of satisfaction. It has a mean of 4.44 and a standard deviation of 1.05.

Discussion and Conclusion

The research focused on the development and evaluation of a Game-Based Learning (GBL) model using Augmented Reality (AR) technology to promote creative problem-solving. The evaluation of the overall quality of the media yielded a mean score of 4.60 with a standard deviation of 0.55, indicating a very good quality level. This high level of quality was consistent across several specific criteria, including Clarity of Information, Visual Presentation, and Technical Performance (AR), all of which scored a mean of 4.80 with a standard deviation of 0.45. These results highlight the effectiveness of AR in enhancing the clarity and visual appeal of educational content, thus supporting learners in understanding complex concepts through immersive experiences. Furthermore, topics such as Accuracy and Credibility, Interactivity, and Accessibility also achieved very good quality ratings, each with a mean score of 4.60 and a standard deviation of 0.55. This indicates that the GBL model effectively provides accurate, credible information and engages learners through interactive AR elements that are accessible to a broad audience. However, the topic regarding the suitability of the duration received a slightly lower score, with a mean of 4.40 and a standard deviation of 0.55, suggesting that while the duration was generally well-received, there may be room for optimization to better meet the needs of all learners. The relevance to learning objectives scored the lowest among the evaluated topics, with a mean of 4.20 and a standard deviation of 0.84, indicating that aligning AR content more closely with specific learning goals could enhance the educational value of the media.

The overall satisfaction with the GBL model was at the highest level, with an overall mean of 4.57 and a standard deviation of 0.76. The visual composition is aesthetically pleasing was particularly praised, scoring a mean of 4.80 and a standard deviation of 0.45, underscoring the importance of aesthetics in educational media. Additionally, the media encourages viewers to contemplate creative problem-solving received a very high satisfaction score of 4.76 with a standard deviation of 0.59, reflecting the success of the AR-enhanced GBL model in fostering critical thinking and creativity among learners. Other topics, such as the media's potential to motivate the audience, content engagement, and the consistency of relevance and clarity, also received very high satisfaction ratings, all above 4.50. This demonstrates that the AR-based GBL model not only captures the learners' attention but also maintains their

interest and motivation throughout the learning process. The slightly lower satisfaction ratings for the suitability of the duration (mean of 4.44, standard deviation of 0.81) and picture clarity (mean of 4.44, standard deviation of 1.05) suggest areas where improvements can be made to enhance learner satisfaction further.

In conclusion, the Game-Based Learning model utilizing Augmented Reality technology proved to be highly effective in delivering high-quality educational media that promotes creative problem-solving. The findings indicate that the integration of AR enhances both the quality and satisfaction levels of educational content. However, to further improve the GBL model, attention should be given to optimizing the duration of the media and ensuring that the content aligns closely with learning objectives. Future research could explore these aspects in more depth, potentially leading to even more effective and engaging educational experiences using AR technology.

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