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ORIGINAL

Leveraging Gamified Mobile Learning and Augmented Reality to Foster Digital Literacy Competencies of University Students in the Society 5.0 Era

Aprovechamiento del aprendizaje móvil gamificado y la realidad aumentada para fomentar las competencias de alfabetización digital de los estudiantes universitarios en la era de la Sociedad 5.0

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ABSTRACT

Digital literacy competencies have become essential for university students to thrive in the era of Society 5.0, where technology and human-centered innovation converge. However, evidence from recent studies and institutional reports indicates that students' levels of digital literacy remain relatively low, highlighting the urgency for effective and engaging learning innovations. This research was designed to develop and evaluate an integrated learning model that combines gamified mobile learning with augmented reality to strengthen students' digital literacy and identify factors supporting its adoption in higher education. The study applied a research and development approach using the Waterfall model to create a mobile application called *AR EduGame*. Data were collected from 112 undergraduate students through needs analysis surveys, pre- and post-tests measuring digital literacy, questionnaires on motivation and engagement, and application usage logs. Quantitative data were analyzed using paired-sample t-tests to determine learning effectiveness, while qualitative responses were examined through thematic analysis. The findings revealed a significant improvement in students' digital literacy, primarily influenced by gamification elements such as points, badges, and leaderboards that enhanced motivation, and by augmented reality features that enabled immersive understanding of complex digital concepts. These results demonstrate the synergistic benefits of integrating gamification and augmented reality, producing stronger learning outcomes than when each is applied separately. In conclusion, *AR EduGame* serves as a validated pedagogical innovation that unites motivation and cognitive depth, offering higher education institutions a practical model to equip students with essential competencies for success in Society 5.0.

Keywords: Digital Literacy; Gamified Mobile Learning; Augmented Reality; Society 5.0.

RESUMEN

Las competencias en alfabetización digital se han convertido en algo esencial para que los estudiantes universitarios puedan prosperar en la era de la Sociedad 5.0, donde convergen la tecnología y la innovación centrada en el ser humano. Sin embargo, los datos de estudios recientes y de informes institucionales indican que los niveles de alfabetización digital de los estudiantes siguen siendo relativamente bajos, lo que pone

de relieve la urgencia de introducir innovaciones de aprendizaje eficaces y atractivas. Esta investigación se diseñó para desarrollar y evaluar un modelo de aprendizaje integrado que combina el aprendizaje móvil gamificado con la realidad aumentada para reforzar la alfabetización digital de los estudiantes e identificar los factores que favorecen su adopción en la educación superior. El estudio aplicó un enfoque de investigación y desarrollo utilizando el modelo Waterfall para crear una aplicación móvil llamada AR EduGame. Se recopilaron datos de 112 estudiantes universitarios mediante encuestas de análisis de necesidades, pruebas previas y posteriores que medían la alfabetización digital, cuestionarios sobre motivación y compromiso, y registros de uso de la aplicación. Los datos cuantitativos se analizaron mediante pruebas t para muestras emparejadas con el fin de determinar la eficacia del aprendizaje, mientras que las respuestas cualitativas se examinaron mediante análisis temáticos. Los resultados revelaron una mejora significativa en la alfabetización digital de los estudiantes, influida principalmente por elementos de gamificación, como puntos, insignias y tablas de clasificación, que aumentaron la motivación, y por funciones de realidad aumentada que permitieron una comprensión inmersiva de conceptos digitales complejos. Estos resultados demuestran los beneficios sinérgicos de integrar la gamificación y la realidad aumentada, lo que produce resultados de aprendizaje más sólidos que cuando se aplican por separado. En conclusión, AR EduGame constituye una innovación pedagógica validada que aúna motivación y profundidad cognitiva, ofreciendo a las instituciones de educación superior un modelo práctico para dotar a los estudiantes de las competencias esenciales para el éxito en la Sociedad 5.0.

Palabras Clave: Alfabetización Digital; Aprendizaje Móvil Gamificado; Realidad Aumentada; Sociedad 5.0.

INTRODUCTION

In the context of Society 5.0, digital literacy has emerged as an essential competency for university students, preparing them to thrive in a rapidly changing technological landscape. Digital literacy encompasses a range of skills, including the ability to access, analyze, and effectively utilize information and digital tools. According to the report from the Indonesian Internet Service Providers Association (APJII), internet access in Indonesia has expanded to cover 77 percent of the population, but the digital literacy level among university students remains low.[1,2] This discrepancy highlights a pressing need for effective educational interventions that can equip students with the digital skills necessary for success in both their academic and professional lives.

The need to strengthen digital literacy has become crucial due to the continuing impact of the COVID-19 pandemic, which has required a rapid shift to remote learning.[3,4] Research shows that students with strong digital competencies are better prepared to participate in online learning environments and to manage the challenges of digital communication and collaboration.[5,6] Moreover, higher levels of digital literacy are associated with improved academic performance, as students are able to leverage digital resources to enhance their learning experience.[7,8] Thus, educational institutions must prioritize the integration of digital literacy training into their curricula to prepare students for the challenges of future employment.

To address these challenges, innovative educational technologies such as gamified mobile learning and augmented reality (AR) have surfaced as promising solutions. Gamification, which utilizes game-like elements to enhance engagement and motivation, has been shown to increase student participation and facilitate deeper learning experiences.[9,10] For example, the use of points, badges, and leaderboards in educational settings has been shown to motivate students to engage with course material and monitor their progress.[11,12] These interactive features also foster a sense of accomplishment, contributing to enhanced academic motivation.[13,14]

At the same time, augmented reality technology provides new opportunities for creating immersive and interactive learning environments. By combining digital content with the physical world, augmented reality enables students to engage with educational material in a dynamic and engaging way.[15,16] Research by Boncu[17,18] indicates that augmented reality applications can enhance the learning experience and help students develop a deeper understanding of complex concepts through visual and experiential learning. The convergence of AR and gamification within a mobile learning framework represents a novel approach to remedy the shortcomings in current digital literacy education.[19,20]

Integrating gamification and augmented reality within a mobile application designed to enhance digital literacy competencies has the potential to create an engaging and effective learning experience for university students.[5,21,22] Although both technologies have been examined in educational contexts, there is still a gap in the literature concerning their combined use. This project aims to fill this void by developing a mobile application that combines gamified elements with AR features to engage students in digital literacy training.[23,24] It is anticipated that such an application can help students enhance their digital skills while enjoying a more interactive and enjoyable learning experience.

To assess the effectiveness of the proposed application, research will be conducted to evaluate its impact on

student engagement, motivation, and digital literacy competencies. By employing quantitative and qualitative methods, the research aims to analyze the interaction between students and the mobile application, measuring improvements in their digital skills over the course of the implementation.[25,26] In addition, the study will examine factors that influence students' acceptance and use of the application, offering insights for educators and policymakers who aim to integrate technology in education.[27,28]

In addition to addressing the practical aspects of the application's development and deployment, this research will identify challenges associated with implementing gamified and AR-driven mobile applications in higher education settings. Issues such as accessibility, institutional support, and the varying levels of technological proficiency among students will be considered.[29,30] The outcomes of this study will contribute to a broader understanding of how innovative educational technologies can be leveraged to cultivate essential digital literacy skills, preparing students to thrive in the technological realities of Society 5.0.[31,32]

Utilizing the potential of gamified mobile learning and augmented reality offers an important opportunity to improve digital literacy among university students. As digital competencies become essential in contemporary society, the successful implementation of this approach can strengthen academic performance and prepare students to navigate the complexities of the modern workforce.[12,33] By fostering a culture of digital literacy through engaging educational technology, universities can prepare the next generation of leaders who are adept at critical thinking, collaboration, and innovation.[34,35] The application is designed to combine the motivational elements of gamification with the immersive features of AR, thereby creating an engaging and interactive learning environment. The research aims to assess its effectiveness in enhancing digital skills, increasing student engagement, and identifying factors that support its adoption in higher education.

METHOD

Research Design

This study employs a research and development approach based on the Waterfall model to design, develop, and implement a gamified mobile learning application integrated with augmented reality for improving digital literacy among university students in the era of Society 5.0. The research produces a fully developed prototype that undergoes systematic testing and evaluation to determine its effectiveness. The study population comprises 350 undergraduate students enrolled in the Faculty of Engineering at Universitas Negeri Padang. From this population, a purposive sampling technique was used to select 112 participants. The inclusion criteria are students enrolled in digital-related courses, possessing Android-based smartphones, and providing consent to participate throughout the study. Exclusion criteria include students who lack access to mobile devices or withdraw from participation, while exit criteria apply to those who do not comply with intervention schedules or fail to complete assessment procedures.

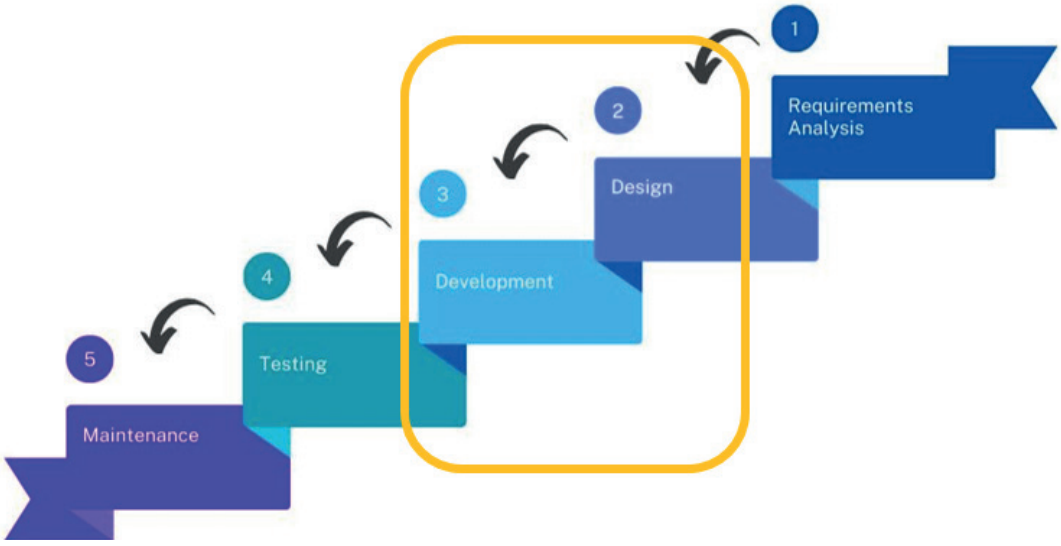

Figure 1. Waterfall Research Model

The research framework presented in the figure highlights the design and development process of a gamified mobile learning application integrated with augmented reality (AR) to foster digital literacy competencies of university students in the Society 5.0 era. Using the waterfall model, the process begins with needs analysis to identify user requirements, followed by application design that integrates gamification elements (points, badges, leaderboards) with AR features for interactive learning. The development stage focuses on prototype creation and content validation, while the testing phase involves classroom implementation to evaluate

usability, effectiveness, and impact on digital literacy. Iterative feedback ensures refinement of the application, demonstrating how the study prioritizes innovative educational technology to prepare students for the digital challenges of Society 5.0.

The variables analyzed include independent variables (use of gamified AR-based mobile application) and dependent variables (digital literacy competencies, student engagement, and motivation). Digital literacy is defined according to current frameworks and measured through validated rubrics, while engagement and motivation are assessed via standardized survey instruments adapted from prior studies. New variables include the integration of AR elements within gamification features, requiring specific observation of student interaction patterns.

Ethical approval will be obtained from the Research Ethics Committee of Universitas Negeri Padang before data collection. Participation will be voluntary, and informed consent will be obtained from all students. Data confidentiality and anonymity will be maintained, and participants will have the right to withdraw at any stage without penalty.

Data Collection Instrument

To ensure comprehensive measurement of the application's effectiveness, multiple instruments were employed in this study. A digital literacy assessment test was developed and adapted from existing frameworks such as the Digital Competence Framework for Higher Education. This test included components measuring information access, analysis, communication, collaboration, and creative use of digital tools. The instrument was piloted with a small group of students before full implementation, and expert validation was conducted with three specialists in digital education and instructional technology to confirm content validity. Reliability testing using Cronbach's alpha was also applied to ensure internal consistency of the assessment items.

In addition to cognitive assessment, questionnaires on engagement and motivation were administered to capture the affective dimension of learning. The questionnaires incorporated elements from the Intrinsic Motivation Inventory (IMI) and the Student Engagement Scale, which were adapted to the context of gamified and AR-based learning environments. These tools measured constructs such as interest, perceived competence, effort, and enjoyment, with items rated on a five-point Likert scale. Prior validation ensured clarity, cultural relevance, and appropriateness for university-level learners in Indonesia.

To complement quantitative instruments, qualitative data collection methods were integrated. Structured interviews and focus group discussions (FGDs) were conducted with students and lecturers to explore their experiences, perceptions, and acceptance of the application. Application usage logs were also collected to examine interaction frequency, time spent on activities, and completion rates of gamified tasks. This triangulation of data sources provided a comprehensive understanding of how the integration of gamification and augmented reality within a mobile application influences digital literacy development in the context of Society 5.0

Data Analysis Techniques

The data analysis process was designed to evaluate the application's impact on digital literacy competencies and student engagement through both quantitative and qualitative approaches. Quantitative data derived from pre- and post-tests of digital literacy were analyzed using descriptive statistics to summarize central tendencies and variability in student performance. Inferential statistics, including paired-sample t-tests, were used to determine differences before and after the intervention, while regression analysis was applied to examine the relationship between application usage and improvements in digital literacy. These analyses provided evidence of the application's effectiveness in enhancing students' digital competencies.

Engagement and motivation survey data were also subjected to statistical analysis to assess changes over time and differences between groups. Factor analysis was conducted to validate the constructs of the adapted instruments, ensuring that engagement and motivation were represented by their respective indicators. Repeated measures ANOVA was used to compare engagement levels across different phases of implementation, and correlation tests were carried out to examine the relationship between students' motivational factors and their digital literacy outcomes. The combination of these analyses provided a robust examination of how gamified and AR-based features influenced affective learning outcomes.

For qualitative data, thematic analysis was conducted using transcripts from interviews and focus group discussions. Coding was performed to capture emerging themes related to usability, interactivity, and perceived learning benefits of the application. Application usage logs were analyzed to identify behavioral patterns, such as the frequency of accessing augmented reality features or progression through gamified tasks. Triangulation of qualitative insights with quantitative results enhanced the overall validity of the findings and provided a detailed perspective on the effectiveness and acceptance of using gamified mobile learning and augmented reality to develop digital literacy competencies among university students in the era of Society 5.0.

RESULT

Requirement Analysis

The literature review in this study centers on three key components: gamification, augmented reality, and digital literacy within the context of Society 5.0. Gamification involves the use of game elements such as points, levels, badges, and leaderboards to enhance student motivation and participation in learning activities. Previous research has demonstrated that gamified digital learning environments can foster engagement and improve learning outcomes. Augmented reality, on the other hand, provides interactive learning experiences by merging three-dimensional digital objects with the real world, enabling students to better understand abstract concepts through experiential learning. Digital literacy in the era of Society 5.0 encompasses the ability to access, interpret, create, and evaluate digital information, serving as a fundamental competency for adapting to rapid technological change.

Student needs were identified through questionnaires administered to 150 respondents from the Faculty of Engineering at Universitas Negeri Padang, selected using a random sampling method, and complemented by interviews with student and lecturer representatives. The findings indicated a strong preference for learning media that is interactive, engaging, and compatible with digital learning habits. However, two key challenges emerged: limited critical ability to evaluate digital information and low motivation for self-directed, technology-based learning. In response, most students expressed positive interest in the integration of augmented reality and game-based elements as potential strategies to enhance their digital learning experience, this is explained in table 1, which are expected to increase their motivation and involvement in the learning process.

Table 1. Analysis of Learning Media Needs and Preferences

Measured Aspect	Percentage
Need for interactive learning media	82 %
Want attractive and digital-friendly media	76 %
Experience difficulty in sorting digital information	64 %
Lack motivation for technology-based independent learning	58 %
Interested in AR-based media	71 %
Interested in challenge systems (game-based challenges)	69 %

The results of the learning media needs assessment show a high demand for innovation and interactivity. Out of 150 respondents, 123 (82 %) stated that they need interactive learning media, and 114 (76 %) expressed a preference for media that is attractive and easy to use. Interest in new technologies and gamification was also evident, with 107 respondents (71 %) indicating interest in augmented reality–based media and 104 respondents (69 %) showing interest in challenge systems or game-based activities.

The survey further revealed several challenges related to digital learning. A total of 96 respondents (64 %) reported difficulty in filtering digital information, indicating limited critical skills in processing online content. In addition, 87 respondents (58 %) reported low motivation for technology-based independent learning. These findings provide an overview of student needs and challenges that must be considered in the development of future learning media.

The developed application has three main components. First, a gamification system consisting of a leveling mechanism where students can level up according to their achievements, points awarded for each learning activity, a leaderboard that displays student rankings to create positive competition, and badges or achievements as a form of reward for certain achievements. Second, digital literacy content in the form of interactive learning modules on topics such as smart and safe internet use, digital ethics, cyber security, and the use of digital devices to support productivity, complete with interactive quizzes to measure student understanding. Third, AR integration that visualizes abstract concepts of digital literacy, such as data security simulations or illustrations of internet networks. This technology is marker-based, allowing students to scan QR codes or specific markers to display 3D objects related to the learning material.

Design

The design of Android-based mobile application architecture is a crucial phase that determines the sustainability, scalability, and maintainability of the software system. This phase not only involves the selection of design patterns—such as MVVM (Model-View-ViewModel) or MVI (Model-View-Intent)—but also establishes a clear modular structure for Separation of Concerns. In the context of modern Android development, a solid architecture must be able to manage the application component lifecycle, ensure efficient data handling, and support adaptation to various device sizes and versions. This introduction will discuss the importance of defining layers (Presentation, Domain, Data) and selecting the right technology to build a reliable, performance-driven application foundation.

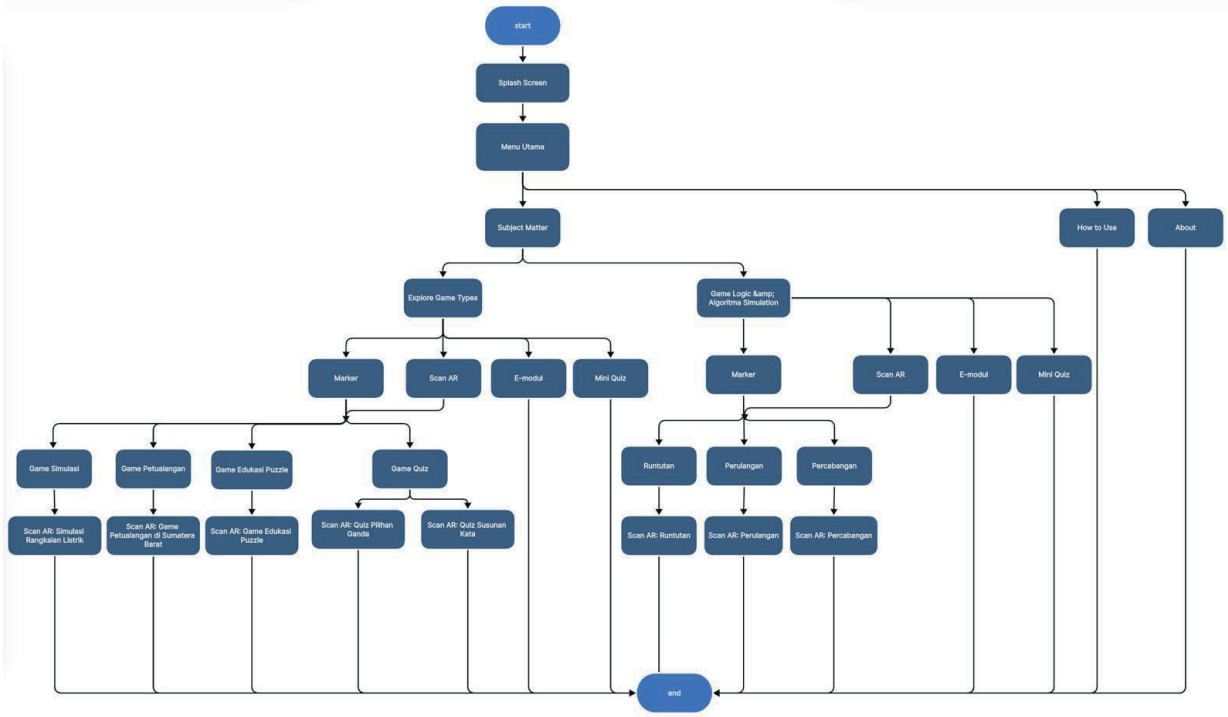

Figure 2. Flow Diagram of the Augmented Reality Application Menu

Figure 2 is a flowchart that represents the comprehensive navigation structure and functionality of an interactive application system with a dual focus on subject matter and logic/algorithm simulation. After initiation (start and Splash Screen), users are directed to the Main Menu, which offers divergent paths: access to main content (Subject Matter and Game Logic & Algorithm Simulation) or supporting information (How to Use and About). In the Subject Matter module, game types (Explore Game Types) include Simulation, Adventure, Educational Puzzles, and Quizzes.

Each game type operates through specific augmented reality scanning procedures (for example, Scan AR Electrical Circuit Simulation or Scan AR Adventure Game in West Sumatra), showing that the game functions depend on AR marker input. The Game Logic and Simulation Algorithms module also divides its content (Propagation, Design, Competition), accessed through corresponding AR scans, demonstrating that the application uses gamification and augmented reality as its primary mechanisms for delivering and interacting with complex learning content. The entire functional flow, from educational material to AR simulation, ends with a single termination point, indicating a well-defined usage cycle for each activity session.

Development

The mobile application implementation phase is a critical point where architectural design and functional planning are translated into fully operational program code on the Android platform. This process involves developing the user interface (UI) using languages such as Kotlin or Java, integrating backend components and local or remote databases, and applying predetermined architectural patterns (for example, MVVM) to maintain modularity and testability. A successful implementation focuses on core functionality while ensuring optimal performance, a responsive user experience (UX), and adaptability across various Android devices. This stage involves precise coding and thorough testing to confirm that the application functions properly and meets the established technical requirements before its release.

Figure 2 shows the interface screen or cover for the “Game Quiz” module of an application called “AR EduGame: Interactive Learning in Game Design.” The background is dominated by dark blue and purple colors with dynamic geometric patterns, giving a technological and educational impression. At the top, the application logo—AR EduGame—emphasizes the use of Augmented Reality (AR) in the context of interactive learning about Game Design. The main focus of the screen is a large neon-style banner with gold-colored text that reads “GAME QUIZ” in the center, surrounded by a purple circle that emits starlight and sparkles. Several question marks (?) float around the banner, creating an atmosphere of mystery and challenge that encourages users to start the game. At the bottom, there is a dark blue interactive button labeled “Game Quiz,” which functions as a call-to-action to begin the quiz activity. Right below it, there are two QR codes in the left and right corners. These QR codes most likely function as AR markers that need to be scanned to activate Augmented Reality-based quiz or simulation content within the app, in line with the app’s name and concept. Overall, this display

is designed to attract attention and encourage users to participate in evaluation or knowledge testing sessions packaged in a game format.

Figure 3. Game Quiz Display

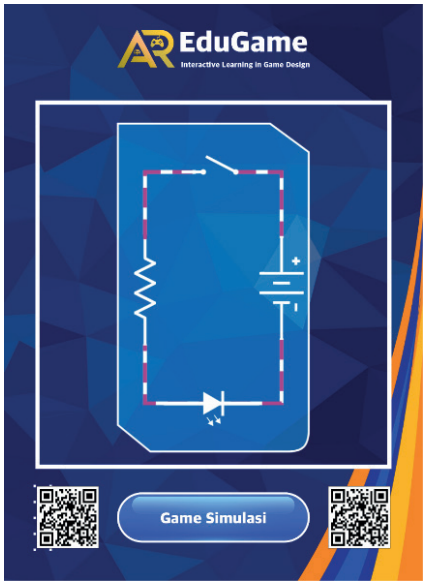

Figure 4. Simulation Game Display

In figure 4 this display serves as both a physical marker and digital cover for the "Simulation Game" module in the AR EduGame: Interactive Learning in Game Design educational application. The background uses a dark blue color palette with modern polygon motifs, reflecting the nuances of technology and science. At the top, the AR EduGame logo emphasizes that this content utilizes Augmented Reality (AR) for an immersive learning experience. The main focus is on a simple electrical circuit diagram displayed in the center of the frame, consisting of a voltage source, resistor, open switch, and diode. The use of pink dotted lines on the circuit indicates that these elements will be animated or simulated through AR. To activate the simulation, users are instructed to scan one of the two QR codes located in the lower corners, which double as AR markers. The "Simulation Game" button between the two QR codes is a call-to-action to start an interactive session, allowing users to observe and manipulate the circuit in a virtual space superimposed on the real world.

Figure 4 serves as the main marker and introductory card for the "Adventure Game" module in the AR EduGame: Interactive Learning in Game Design application framework. With a dark blue background decorated with technological motifs and the AR EduGame logo highlighting the integration of augmented reality, this card communicates its educational and interactive nature. The center of attention is a cartoon-style adventure map showing a winding path across landmarks resembling locations in West Sumatra, such as rumah gadang and clock towers, along with a compass. Three numbered checkpoints (1, 2, and 3) mark the stages of progression in the learning narrative. To begin this exploration, users are instructed to use the "Adventure Game" button

and scan one of the two QR codes at the bottom. These QR codes act as AR markers that trigger virtual content, transforming this static map into an AR-based gamification and exploration experience.

Figure 5. Adventure Game Display

Figure 6. Puzzle Game Display

In figure 6, this display serves as a marker and introductory card for the "Puzzle Game" module in the AR EduGame: Interactive Learning in Game Design application. The background is consistent with the dark blue color scheme and technological accents of the application, and the AR EduGame logo at the top emphasizes the role of Augmented Reality (AR) in the game design learning process. The main visual focus is on an iconic image of a mosque displayed in an unsorted 3x3 puzzle format. This image shows distinctive architecture with a wide, multi-level roof and tall minarets, which represents an Islamic landmark in Indonesia (such as the Grand Mosque of West Sumatra). The presentation of the image as separate puzzle pieces hints at the interactive nature of this module, where users are required to reassemble it. At the bottom of the screen, the "Game Puzzle" button serves as a call-to-action to start the activity. This button is flanked by two QR codes that serve as AR markers. When one of these codes is scanned by a mobile device, virtual puzzle pieces will likely appear in the real world, allowing users to interact and complete the puzzle in an Augmented Reality environment. Thus, this display combines elements of cultural education and visual-spatial skills in an engaging game format.

Gamified content was developed to support students' digital literacy through various interactive approaches. Digital literacy modules in the form of text, video, and short simulations were compiled based on literature studies and student needs analysis. Each module is equipped with multiple-choice quizzes, drag-and-drop exercises, and simple mini-games to reinforce understanding. Points and XP are awarded each time students complete a module or quiz. Leaderboards are developed in two categories: per class (specific course classes)

and global (between batches), to increase competitive motivation. Badges are also integrated to recognize certain achievements, such as "Digital Beginner," "AR Explorer," or "Top Learner." All progress is stored in a database and can be monitored by students through their respective profiles.

AR integration is done using ARCore for Android and Vuforia as an alternative for wider compatibility. This technology is used to display interactive 3D objects relevant to digital literacy material, such as technology device simulations, internet network representations, or digital security visualizations. QR Code-based markers or image recognition are used as triggers for the appearance of 3D objects. Objects are developed in GLTF/GLB format with polygon optimization to maintain good performance on mid-range devices. User interactions in AR include rotation, zoom, animation, and object-based quizzes. In addition, a fallback mode is provided in the form of non-AR content so that students can still access the material if their devices do not support AR.

DISCUSSION

The purpose of this study was to examine the effectiveness of an integrated learning model that combines gamified mobile learning and augmented reality to enhance digital literacy among university students in the context of Society 5.0. This integration was designed to bridge the gap between technological progress and students' readiness to use digital tools with understanding and purpose. The findings show that the combination of gamification and augmented reality improved students' digital literacy competencies, with clear gains in analytical and creative aspects.

The improvement in digital literacy reflects how motivational and cognitive factors can work together when both technologies are applied in one framework. Gamification supports engagement and persistence, while augmented reality enables experience-based understanding of complex digital ideas. This outcome aligns with Hagerman and Özcan[9,19] who found that elements such as points, badges, and leaderboards can strengthen engagement and autonomy in learning. The present study extends this perspective by showing that when gamification merges with visualization through augmented reality, students show deeper learning and stronger involvement in the process.

Parallel to the motivational role of gamification, the contribution of AR was equally important in enriching cognitive engagement. Existing studies Haruna and Wei[15,20] confirmed that AR can enhance comprehension of abstract and complex concepts by providing interactive and immersive learning experiences. The results of this research extend previous studies by showing that augmented reality enabled students to visualize advanced digital concepts, such as cybersecurity protocols and technological infrastructures, in more meaningful and contextualized ways. This approach facilitated deeper learning and retention, contributing to improvements in critical digital literacy competencies.

The novelty of this research lies in demonstrating the synergistic effect achieved when gamification and AR are integrated into a single learning model. While previous research has separately validated the effectiveness of gamification and AR in education, few studies have empirically explored their combined impact. By merging the motivational stimulus of gamification with the cognitive depth of AR, this study contributes a unique and more powerful framework for developing digital literacy competencies. This integrated approach addresses a gap identified by earlier scholars,[23,30] who called for further research into the simultaneous application of these two technologies in higher education contexts.

Furthermore, the competencies measured in this study extend beyond technical operational skills to include advanced abilities such as critical analysis, evaluation, and the creation of digital content. These outcomes align with the multi-dimensional framework of digital literacy presented in the Introduction. They also resonate with studies by Liu and Rzabayeva,[5,7] which demonstrated that higher levels of digital literacy contribute to better academic performance and professional readiness. By confirming these relationships, the present study provides strong empirical evidence that immersive and student-centered learning models can bridge the gap between current educational practices and the demands of Society 5.0.

From a practical perspective, the study underscores the importance of incorporating advanced technologies into higher education curricula. The Results highlight that blending gamification and AR not only improves digital literacy but also cultivates transferable skills such as collaboration, critical thinking, and problem-solving. This finding is consistent with Boncu,[17] who emphasized the role of gamification in promoting autonomy and competence, and Wei,[20] who validated AR's role in cognitive engagement. Furthermore, the competencies measured in this study extend beyond technical operational skills to include advanced abilities such as critical analysis, evaluation, and the creation of digital content. These outcomes align with the multi-dimensional framework of digital literacy presented in the Introduction.

Despite these promising results, successful implementation requires careful consideration of contextual challenges. As noted in prior studies Ng,[25] issues such as infrastructure readiness, equitable access to mobile devices, and faculty professional development must be addressed to ensure sustainability. While this study demonstrates the pedagogical potential of gamification and AR, further research should employ longitudinal designs to evaluate long-term impacts on career readiness and compare the model's effectiveness with other

immersive technologies, such as Virtual Reality (VR). Such investigations will broaden the applicability of this model and strengthen its contribution to pedagogical innovation in higher education.

Implication

The findings have several major implications for both educational practice and policy development. The success of the integrated model indicates that a shift in instructional design is needed, moving from conventional methods toward the use of immersive and engaging technological tools to build essential digital competencies. Institutions of higher education are encouraged to invest in the necessary technological infrastructure, including high-performance mobile devices and strong network connectivity, to support the implementation of augmented reality–based and gamified learning experiences across departments. In addition, this study highlights the need for continuous professional development programs to strengthen faculty members' technological pedagogical content knowledge (TPACK), enabling them to design, manage, and facilitate learning in complex digital environments, and ensuring that educational outcomes align with the competency requirements of the global digital workforce.

Limitations and future research

The study has certain limitations. The research was conducted over a short period, which restricts the generalization of the long-term sustainability of the observed improvements in digital literacy and student motivation. In addition, the reliance on a single institutional setting limits the external validity of the findings, as student acceptance and technology infrastructure vary across universities. For future research, it is recommended to conduct longitudinal studies to monitor the lasting effects of the integrated model on students' career development and adaptive abilities. Further comparative studies are also needed to compare the effectiveness of the gamified mobile augmented reality model with other immersive technologies, such as full virtual reality, and to examine its application across a wider range of academic disciplines to expand the body of knowledge on technology-enhanced learning.

CONCLUSION

This study aimed to develop and assess an integrated learning model, AR EduGame, which combines gamified mobile learning and augmented reality to strengthen the digital literacy competencies of university students in the context of Society 5.0. The work achieved its objective by designing and validating a model that links motivation and cognition within one learning framework. The integration of game-based elements and augmented reality demonstrates the value of uniting engagement and conceptual understanding in higher education. The outcomes of this study contribute to the broader field of technology-enhanced learning by presenting a model that supports the development of essential digital competencies required in the modern era. Beyond its immediate educational benefits, the model offers a foundation for future pedagogical innovation and curriculum design. Higher education institutions can adapt this approach to foster student readiness for the evolving demands of the global workforce and promote more active, meaningful, and creative learning experiences.

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CONFLICT OF INTEREST

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