Penerbit Akademia Baru

Journal of Advanced Research Design

Journal homepage:
https://akademiabaru.com/submit/index.php/ard
ISSN: 2289-7984

Development of Digital Games as Problem Solving-Based Learning Media using Game Development Life Cycle

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ARTICLE INFO

Article history:
Received 7 February 2025
Received in revised form 28 February 2025
Accepted 30 June 2025
Available online 20 July 2025

Keywords:
Game education; learning media; problem-based learning; game development life cycle; UEQ; higher education

ABSTRACT

The development of digital games as learning tools holds significant potential for enhancing student motivation and engagement in the teaching and learning process. As problem-solving-based learning media, digital educational games offer benefits such as fostering critical thinking, creativity and problem-solving skills. Despite these advantages, higher education at Muhammadiyah University of Riau remains predominantly conventional, with game-based learning methods yet to be implemented. This study aimed to develop a digital educational game that supports constructive student learning. The research utilized a development research approach, employing the Game Development Life Cycle (GDLC) method. The findings demonstrated the GDLC method's effectiveness in creating educational games for students. Alpha testing revealed that all game features functioned properly and usability testing, conducted with 50 students using the User Experience Questionnaire (UEQ), yielded positive results. The average scores were as follows: Attraction (5.94), Clarity (6.02), Efficiency (6.38), Accuracy (6.12), Stimulation (5.66) and Novelty (5.80). Implementation trials employed a quasi-experimental design with control and experimental classes to assess the impact of the developed educational game on students' problem-solving abilities. The results showed statistically significant differences between the experimental class, which used the game and the control class, which did not. The t-count value for the experimental class was 55.934, compared to 43.987 for the control class, indicating a stronger improvement in problem-solving skills among students who engaged with the educational game. This study highlights the potential of digital educational games as effective tools for modernizing higher education and improving student outcomes.

1. Introduction

Technology has become an integral part of daily life in the rapidly evolving digital age, transforming numerous aspects of our routines and interactions. Education, too, has been profoundly impacted, as technology continues to reshape teaching and learning strategies. One

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https://doi.org/10.37934/ard.137.1.151166

notable educational innovation is the use of digital media, such as digital games, as learning aids [1,2]. The development of digital games as learning media has the potential to significantly boost student motivation and involvement in the teaching and learning process. Digital educational games, as problem-solving-based learning media, offer significant benefits in fostering critical thinking skills, enhancing creativity and improving students' problem-solving skills [3]. According to Choo *et al.,* [4], Generation Z has increasingly gained recognition for its distinct traits and behaviours, shaped by growing up in a digital world filled with smartphones, the internet, social media and online shopping. Hence, games not only foster a fun and dynamic learning environment but also enable students to engage in practical, contextualized learning. Through gaming scenarios and challenges, students can apply their knowledge and develop essential problem-solving techniques.

Digital educational games in the college settings [5] are multifariously termed such as digital game-based learning (DGBL) and digital educational games [6] and game-based learning [7]. These games are intended to interest and excite students as they learn complex subjects such as mathematics and calculus, to improve critical thinking, problem-solving skills and overall learning outcomes. Research highlights that digital educational games can positively impact students' attitudes, intentions and behaviours toward learning. They encourage environmentally conscious perspectives and provide immediate feedback, which enriches the learning experience. Adanali *et al.,* [8] emphasise that elements such as game structure, engagement, appeal, attention, relevance, satisfaction and cognitive investment are all important factors for fostering students' motivation and sustaining commitment to learning through digital games in higher education settings. Although digital games have immense educational potential, their adoption and development face several problems. These constraints include limited resources, the difficulty of creating educational and compelling games and the requirement for effective integration of learning content with game dynamics.

Several research studies have looked into the use of digital problem-based educational games grounded in Problem-Based Learning (PBL) within higher education settings. Studies have indicated that PBL improves competency, motivation and learning experiences, emphasizing the necessity of providing students with actual learning circumstances [9]. Furthermore, von Thienen *et al.,* [10] argues that the integration of digital game-based learning media, such as Scratch, dramatically increases students' problem-solving skills, motivation and overall learning experiences, encouraging critical, creative and problem-solving skills relevant to the digital age. Furthermore, the successful implementation of PBL in higher education during the digital age necessitates a strong technology infrastructure, comprehensive faculty training, well-designed curriculum, effective student support and appropriate assessment strategies. These are crucial for developing critical thinking, collaboration and digital literacy – skills essential for preparing students for future careers. Collectively, all of the aforementioned studies underscore the efficacy of PBL and digital game-based learning in improving student engagement, problem-solving abilities and overall learning results in higher education.

The Game Development Life Cycle (GDLC) is an effective method for developing digital games for learning purposes. GDLC is a systematic framework for digital game development that incorporates the phases of planning, design, development, testing and maintenance. According to Roedavan *et al.,* [11], this framework may allow developers to verify that their games fulfil high-quality requirements and align with the desired learning objectives. GDLC is an important strategy for developing digital educational games for students. It has numerous stages, including initiation, pre-production, production, testing, beta and release. The GDLC approach attempts to build interactive and engaging educational games that aid in the learning process by using components such as Socially Conscious Design (SaWD) principles, which take into account the characteristics of learners and instructors, learning theories and evaluation criteria. Digital games based on opinions Sampaio *et al.,* [12] for students bridge the gap between theory and practice, shifting students from passive to active learners through engaging activities that inspire and facilitate problem-solving while delivering an immersive learning experience. Furthermore, Educational games for university students in the Informatics Education program, particularly in the Algorithm and Programming course, serve as an interactive tool to enhance understanding of fundamental concepts such as logic, data structures and algorithm design. These games foster problem-solving skills by simulating real-world challenges, encouraging students to debug, optimize and create efficient solutions. By incorporating elements like level-based progression, instant feedback and gamified rewards, they increase motivation and engagement while promoting computational thinking through decomposition, pattern recognition and abstraction. Additionally, collaborative features in multiplayer or team-based modes enhance communication and teamwork. As a formative assessment tool, educational games also measure students' performance in real-time, preparing them with the practical skills and mindset needed to tackle industry challenges effectively.

The goal of this research is to develop a digital educational game centred on problem-solving to serve as a learning medium utilizing GDLC. This project is expected to make major contributions to the development of new and effective learning media, as well as practical recommendations for developers and educators on building and implementing digital games in educational settings.

2. Methodology

Designing educational games in digital system lectures for students is a development research project. Development is carried out based on prior learning, which is then supplemented with different forms of educational games centred on problem-solving. Education, psychology, game design, information technology and art are all areas that contribute to educational game development studies. Collaboration among professionals from various fields is required to ensure that the games generated are not only fascinating and entertaining but also effective in meeting educational objectives.

This study used the Game Development Cycle as its development method. The GDLC technique consists of four major phases that incorporate development patterns utilized in both amusement and serious games. The iterative GDLC approach was chosen for its greater flexibility in adapting to changing requirements, compared to the more rigid linear GDLC approach. The GDLC scheme (Figure 1) employed in this work incorporates the design [11].

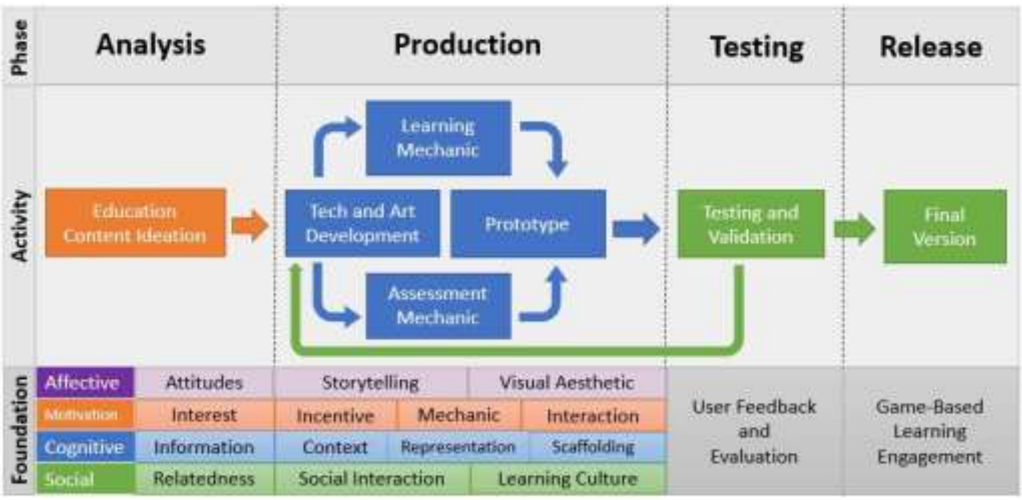

Fig. 1. GDLC model

2.1 Analysis

The analysis phase in this study aims to define the background, objectives and types of educational game content implemented in the system. The analysis was conducted on the following points:

i. Conducting an initial needs analysis based on the semester learning plan document, learning needs analysis, student learning styles and game-related experiences.
ii. Analysing the necessity for UI/UX design of game designs that suit student needs.
iii. Design and gamification components for multimedia and hypermedia displays.
iv. Implementing problem-based learning models in educational games to enhance student learning capacities.

2.2 Production

Educational game production involves translating the results of the analysis into various game elements. The stages of developing an educational game design are as follows:

2.2.1 Developing technology and interface art display

In the Tech and Art Development stage, technology and art studies are produced in a disciplined and collaborative manner, allowing educational games to be established on a solid basis, both technically and artistically and ready to be further developed into a high-quality final product. Some activities at this stage include selecting the appropriate development platform and tools, designing an efficient and modular code structure to ensure that the game is easy to maintain and scale and developing character concepts, environments and other visual elements that support the game's narrative and educational goals.

2.2.2 Learning mechanisms in the game

After determining the learning objectives, the following stage is to develop the learning mechanisms that will be incorporated into the game. These strategies should effectively help students attain their learning objectives. Puzzles, quizzes, simulations, interactive case studies and project-based activities are some examples. The design should incorporate relevant learning theories, such as constructivism and problem-based learning, to guarantee that students are actively and contextually involved in the learning process. After the design is accepted, the developer begins implementing the learning processes in the game. This includes programming the learning logic, developing educational content and including accompanying visual and auditory features.

2.2.3 Assessment mechanisms

These mechanisms should be designed to automatically and objectively assess player progression and performance. Assessment modalities include interactive quizzes, timed tasks, project assessments and scenario simulations. These designs should enable precise measurement and provide relevant feedback to players. This stage involves incorporating assessment methods into the gameplay. Assessments should be made to be a natural part of the gameplay experience, rather than an interruption.

2.2.4 Prototyping the game

After finishing the Tech and Art Development, Learning Mechanics and Assessment Mechanic stages, the first step in prototyping is to collect all of the components that have been created. This contains visual and aural aspects from the Tech and Art Development stages, learning processes from the Learning Mechanic and assessment scoring systems. All of these components must be ready for integration into a playable early version of the game. Tools for development in the research are by using Figma for UI/UX Design, Unity for develop the game environment and also Blender to develop the object of the avatar.

2.3 Testing

Testing is an important stage in the game development process that ensures that the game runs smoothly, is bug-free and provides an optimal user experience. The following are the steps of testing performed in GDLC:

i. Alpha Testing: The development team does alpha testing and quality assurance (QA) is done internally. This testing focuses on discovering and resolving game bugs and issues. This testing encompasses all components of the game, including game logic, user interface (UI), learning methods and scoring.
ii. Usability Testing: focuses on how players interact with the game and whether the user interface is intuitive and simple to use. This testing contains a questionnaire for collecting comments. The User Experience Questionnaire (UEQ) was employed, which consisted of 26 questionnaire items by Schrepp *et al.,* [13]. This usability assessment included 50 students from the Faculty of Teacher Training and Education at Muhammadiyah University of Riau who were enrolled in the Informatics Education study program. In this study, the entire population served as a sample for usability testing.

2.4 Release

The release stages in educational games include not only the technical requirements of releasing, but also marketing tactics, customer support and a dedication to constantly enhancing the game's quality and instructional value. By following this method step by step, educational games can be successfully released to the market and give users valuable learning experiences.

3. Results
3.1 Development Results

Data on the demands of the educational games developed were derived from the results of a needs analysis questionnaire completed by 256 students at the Faculty of Teacher Training and Education from the 2020 to 2023 intake. The respondent data are as a Table 1 follows:

Table 1
Respondents of game need analysis

Class Year	Men	Women	Total
2020	25	38	63
2021	36	32	68
2022	28	34	62
2023	31	32	63
Total Respondents	256		

The user needs analysis indicates that students prefer educational games that are interactive, demanding and relevant to the lecture subject. Survey results also show that the majority of respondents believe that educational games may help them comprehend difficult subjects in a more entertaining and comprehensive manner. Here are some of the key findings from the questionnaire replies that were collected:

i. Interactivity: Students prefer interactive features in games that enable them to actively participate. This includes simulation-based assignments, interactive quizzes and problem-solving activities.
ii. Gradual Difficulty Level: Games should have slowly increasing levels of difficulty so that students can improve their skills over time. This will also assist in keeping motivation and interest up during the game.
iii. Relevance to Curriculum: Game content must be aligned with the course material being taught. This integration ensures that the game is not only fun but also supports the achievement of academic learning goals.
iv. Feedback and Evaluation: The real-time feedback feature is highly valued because it allows students to immediately identify and correct their mistakes. Furthermore, quarterly performance evaluations will provide a measurable way to track their learning progress.

From qualitative and quantitative analysis, some of the game features that students most include:

i. High-Quality Graphics and Audio: Engaging visuals and audio enhance the gaming experience and aid in understanding the material.
ii. Multiplayer Mode: This feature allows collaboration between students, which not only increases engagement but also encourages cooperative learning.
iii. Customizable Avatars: Allowing users to customize their avatars boosts the sense of ownership and personalization in the game.

In addition to the preferences and game features that students are interested in, students provided feedback on the subjects that need to be created to meet the needs of educational game users. The results of the questionnaire that the students have filled out are as in Figure 2.

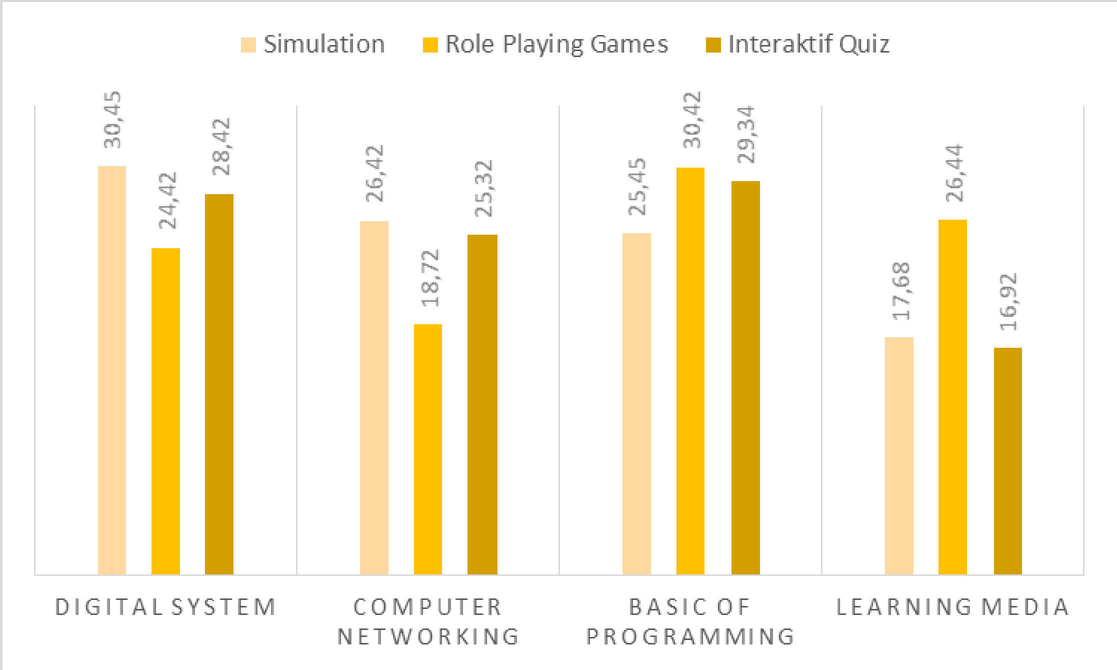

Fig. 2. Types of educational game needs

The figure above depicts students' preferences for three types of educational games (Simulation, Role-playing games and Interactive Quizzes) in all four subjects (digital systems, computer networking, basic programming and learning media). The analysis results reveal that students are more interested in educational games that are both simulative and interactive. This is understandable because educational games enable students to learn directly and actively. Simulation educational games allow students to imitate a variety of events and conditions, making learning easier and more enjoyable. Role-Playing Games Educational games enable students to play roles in a variety of circumstances and conditions, allowing them to learn more creatively and critically.

Based on the data, educational games are developed in accordance with the needs. This is the most important stage, namely production. The game's concept is a runner game with a serious gaming genre, classic and futuristic themes and hypermedia features. This game design is known as Digital System Running. The game specifications can be discussed in the Table 2 below.

Table 2
Specification of game development

No.	Description	Description
1	Game Name	Digital System Running
2	User	Student
3	Genre	Runner Game, Serious Game
4	Gameplay	Running game, grab the point
5	Game Mechanic	Collecting badge as many as possible, answering question to obtain badge
6	Characters	Characters are male student and female student
7	Challenge	A college student who runs to solve various problems in course digital system
8	Gamification	Point, Badge, Punishment, Lifetime
9	Platform	Mobile Application

One of the stages of production activities is the ability to design a gamification mechanism that meets the game's requirements. The results of designing the game mechanism can be described as a Use Case for the game under development. In digital game design, a Use Case is a detailed description of how users interact with a game system to achieve a particular goal according to Khaldi *et al.,* [15]. Use Cases are critical for driving the design and development process and ensuring that the game satisfies user needs and expectations. This part contributes to defining the game's functioning, specifying various user interaction scenarios and determining the system's response to these actions. Use Cases can also help to promote autonomy among end users, as illustrated in the case of building digital games for therapeutic reasons, where web system support promotes participant autonomy in the design process. The following Figure 3 depicts the planned Use Case.

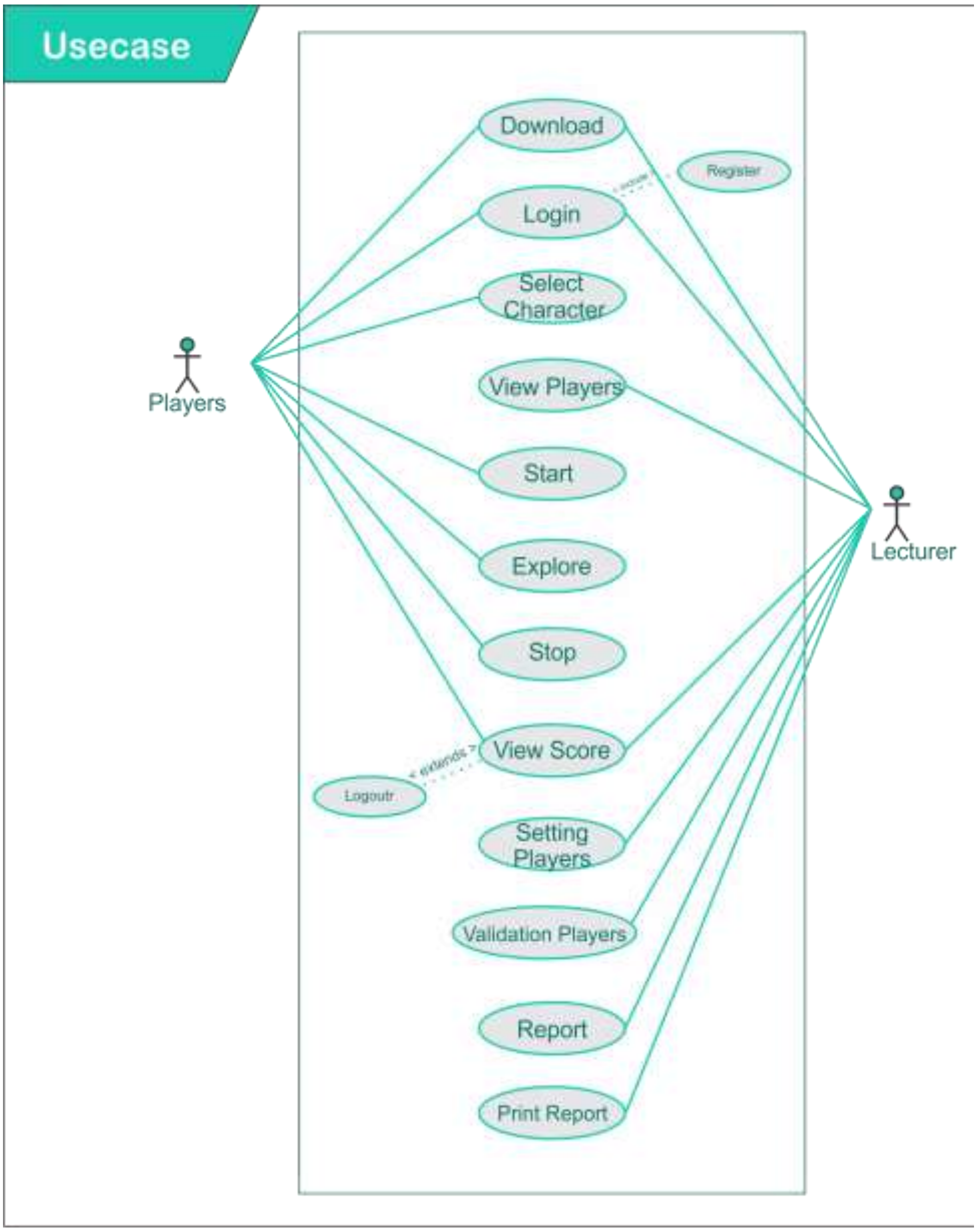

Fig. 3. Use case of game development

The following stage, based on the use case, is to design an activity diagram for the game's operating processes. The activity diagram is created so that the game flow and gamification can be implemented in game programming. The activity diagram is presented in the Figure 4 below.

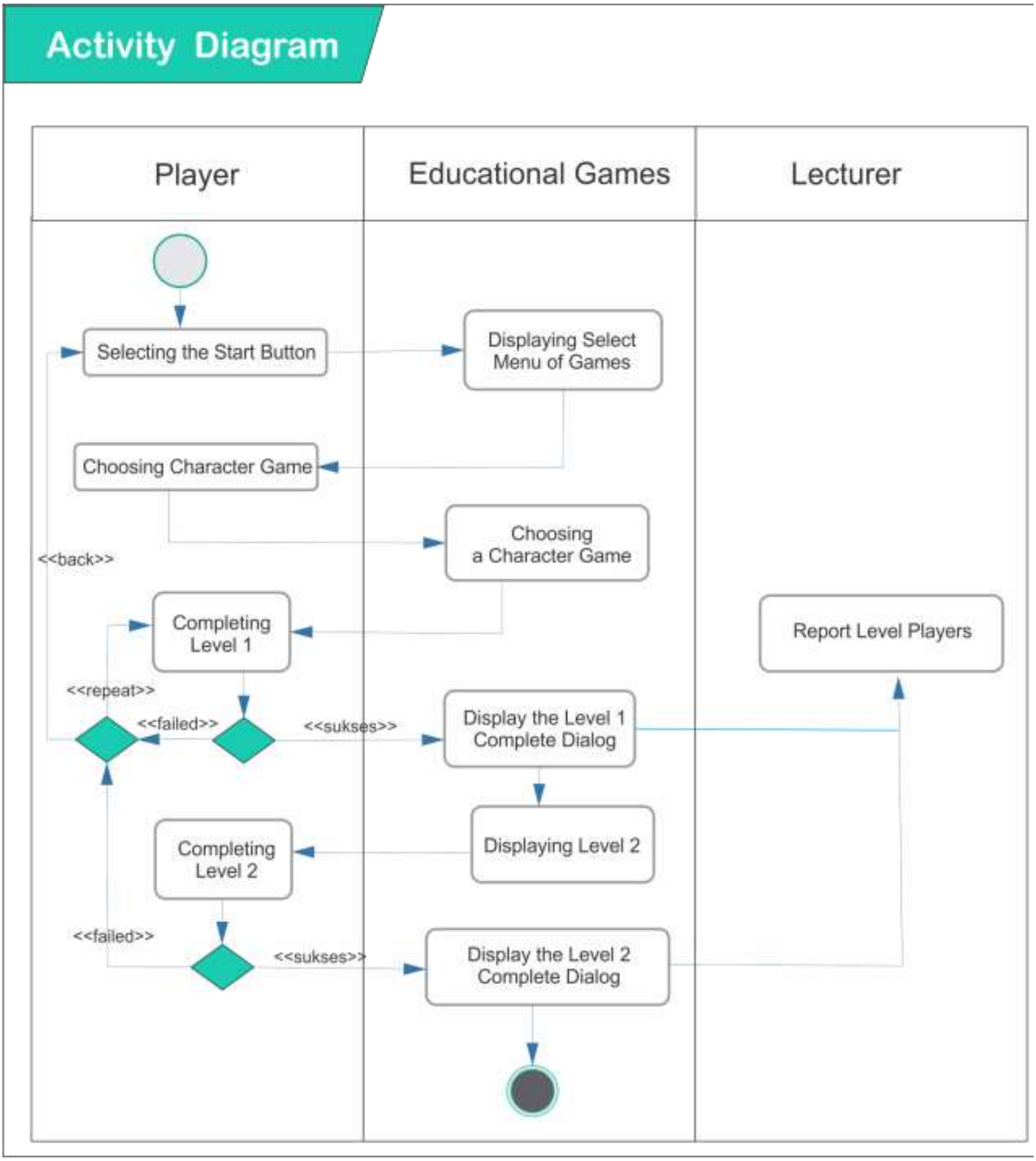

Fig. 4. Activity diagram of game development

Following the completion of the game flow design, each game's user interface is designed. The user interface is designed using needs analysis, course characteristics and lecture outputs. This game's user interface was designed using the Figma tool, which is available for building user interfaces. The UI development process for the game design can be seen in the Figure 5 below.

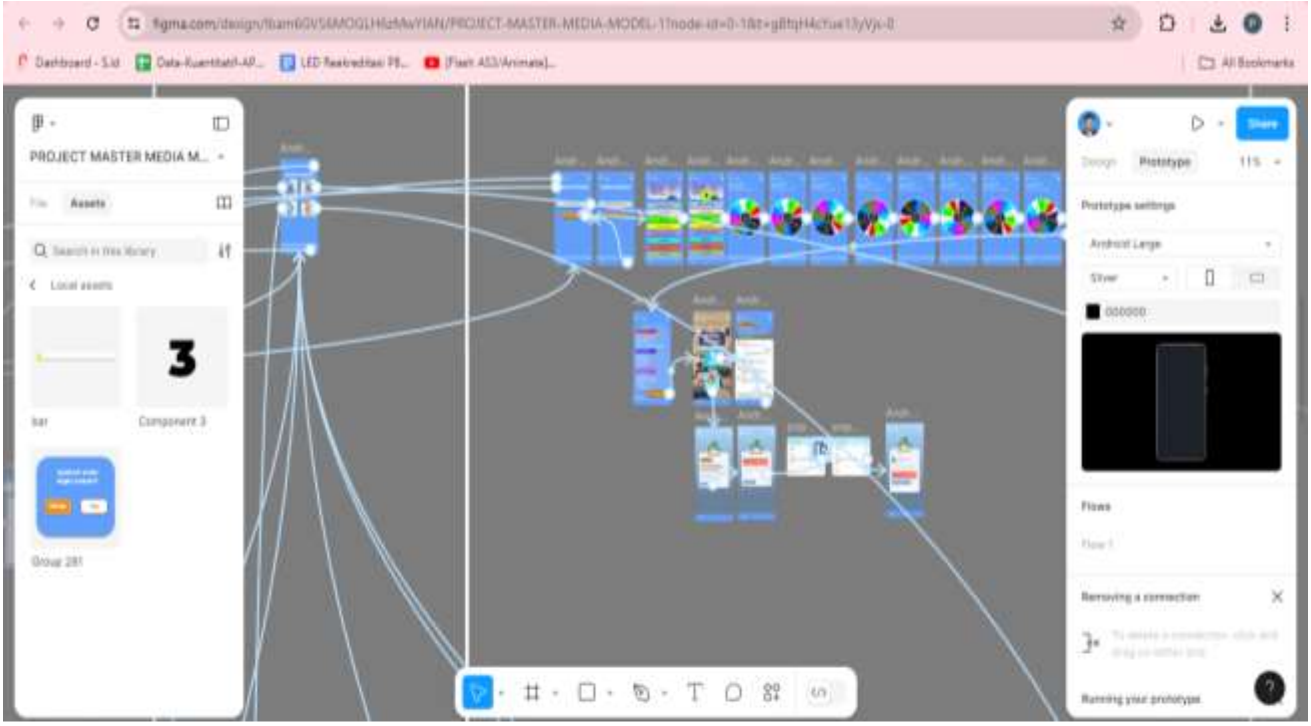

Fig. 5. The implementation of UI design

The Figma application is useful for creating the interface's presentation, flow and prototyping before moving on to the implementation step. The following Figure 6 depicts the gamification display for each game developed with Figma.

a b c d

Fig. 6. (a) The design of game initial display (b) The display material in the game (c) Runner game display from application (d) Score display after playing the game

After the game design and game prototyping are completed, the next stage is testing the game prototyping that has been developed. The results of the alpha and beta tests that have been carried out can be seen in the following Table 3.

Table 3
Blackbox test results

No.	Test Class	Test Item	Test Type	Test Result
1	Home Page	Choosing every menu at home page	Blackbox	Successful
2	Material Page	Video and material display	Blackbox	Successful
3	Game Page	Game smoothness and point calculation	Blackbox	Successful
4	Quiz Page	Choosing answer and score calculation	Blackbox	Successful
5	Leaderboard Page	Choosing information of game achievement	Blackbox	Successful

During the beta stage, usability testing is undertaken. This testing contains a questionnaire for collecting feedback. The questionnaire utilized was the User Experience Questionnaire (UEQ), which had 26 questions. The UEQ instrument used is a modification based on the software assessment instrument developed [14]. Data is collected through questionnaires that are given directly when the subject is testing the application that has been developed. Respondents in this usability assessment were 50 students from the faculty of teacher training and education at the Muhammadiyah University of Riau studying informatics. In this study, the entire population served as a sample for usability testing. The test results are presented in the table below.

Table 4
Result of usability testing

Aspect	Average	Standard Deviation	N
Attractiveness	5,94	1,06	50
Clarity	6,02	1,06	50
Efficiency	6,38	0,85	50
Accuracy	6,12	0,98	50
Stimulation	5,66	1,22	50
Novelty	5,80	1,05	50

Overall, the user experience with the tested product is fairly positive. This is observed in the average score for all aspects, which is greater than 5.50. In terms of attractiveness, people typically believe that the product is fascinating and enjoyable to use. Nevertheless, there is still space to increase its attractiveness, for example by adding a more appealing design or more inventive features. In terms of overall clarity, the instructional game application design is simple to understand and utilize. Users believe that the product is simple to use and quick to perform tasks. Educational games have the greatest average rating from users, showing that they believe this program is efficient. Users typically believe the product can deliver accurate and dependable information. Accuracy in application design is critical for products that handle sensitive or vital information. Stimulation in the game gets a rating of 5.66. Based on these findings, there is still space for improvement in product stimulation, such as by incorporating more interactive or gamified aspects. Users generally believe that the game offers something unique and different from other products on the market. However, there is still room for improvement in product originality, such as by introducing truly innovative or previously unknown features.

3.2 Implementation

Following the beta test, the game was implemented to evaluate its effectiveness in enhancing students' problem-solving skills. To gather this data, a learning trial was conducted using a quasi-experimental approach. The specific quasi-experimental design applied in this study was the non-equivalent group pre-test and post-test design. The details of this research design are presented in Table 5.

Table 5
Experiment design

Group	Respondent	Measurement	Independent Variable	Measurement
Control Class	NE	Q1	X1	Q3
Experiment Class	NE	Q2	X2	Q4

Note:
NE : Non-equivalent respondent group
Q1 : Problem-solving skills – pre in the control
Q2 : Problem-solving skills – pre in the experiment
Q3 : Problem-solving skills – post in the control
Q4 : Problem-solving skills – post in the experiment
X1 : Teaching and learning with the conventional methods
X2 : Teaching and learning with the Game-based Learning

The population in this research consisted of 184 second year students of FKIP Muhammadiyah University of Riau who were taking Algorithm and Programming Course. The research will take place in the Even semester 2023/2024. Sampling uses a cluster sampling technique by selecting samples in groups. The sample size was 102 students consisting of 52 students in the experimental group and 50 students in the control group. Before participating in the research process, research subjects received an explanation regarding the research objectives and research procedures. Subjects were also asked to declare their participation in this research voluntarily.

The research aims to test the effectiveness of Game-based learning on the problem solving of university student. The research instrument used was a problem-solving test. The test was developed in the form of essay test of five questions, referred to the learning materials of basic of programming and algorithm, course learning outcomes, problem solving skill indicators as well as the assessment rubrics. The assessment of creativity employed the problem-solving assessment rubrics.

The instrument was tested for validity and reliability through a pilot study involving 30 students outside the research sample. The validity test result using moment product correlation and the reliability result using Cronbach's Alpha are presented in Table 6 below.

Table 6
Validity and reliability test result

No.	No Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Cronbach's Alpha if Item Deleted	Reliability Statistics (Alpha Cronbach)
1	Item 1	18,4356	46,987	,678	,701	,890
2	Item 2	19,2454	45,567	,786	,671	
3	Item 3	17,7875	43,567	,545	,845	
4	Item 4	18,7873	70,456	,589	,890	
5	Item 5	20,245	71,567	,556	,806	

The data of the students' problem-solving skill before and after the treatment in the experimental and control groups are reported in Table 7.

Table 7
Descriptive statistics of problem-solving skill

Treatment	Group	Minimum	Maximum	Mean	Standard Deviation
Before	Experimental (N=52)	10.00	50.00	29,807	11,797
	Control (N=50)	10.00	50.00	28,00	12,454
After	Experimental (N=52)	75.00	95.00	86,92	5,786
	Control (N=50)	60.00	85.00	71,60	7,521

In general, all statistical metrics for both groups showed higher values after the treatment compared to before. Prior to the treatment, most figures in the experimental group exceeded those in the control group, although the standard deviation of the control group (12.454) was almost identical to that of the experimental group (11.797). Regarding minimum scores, both the experimental and control groups had the same minimum score (10) before treatment. After treatment, the minimum scores of both groups increased, but the increase in the experimental group (75.00) surpassed that of the control group (60.00).

In terms of maximum scores, the experimental group outperformed the control group before the treatment. Following the treatment, both groups showed improvements in their maximum scores; however, the increase in the experimental group (75.00) was greater than in the control group (60).

When considering average scores, both groups had relatively low averages score before the treatment. After the treatment, there was a significant rise in the average scores of both groups, with the experimental group (86.92) achieving a higher average than the control group (71.60). For standard deviation, the control group had a higher value than the experimental group before treatment. Post-treatment, both groups saw an increase in standard deviation, but the experimental group had a higher standard deviation compared to the control group. The data distribution of students' problem-solving skills, as measured in the pre- and post-tests, is illustrated in Figure 7.

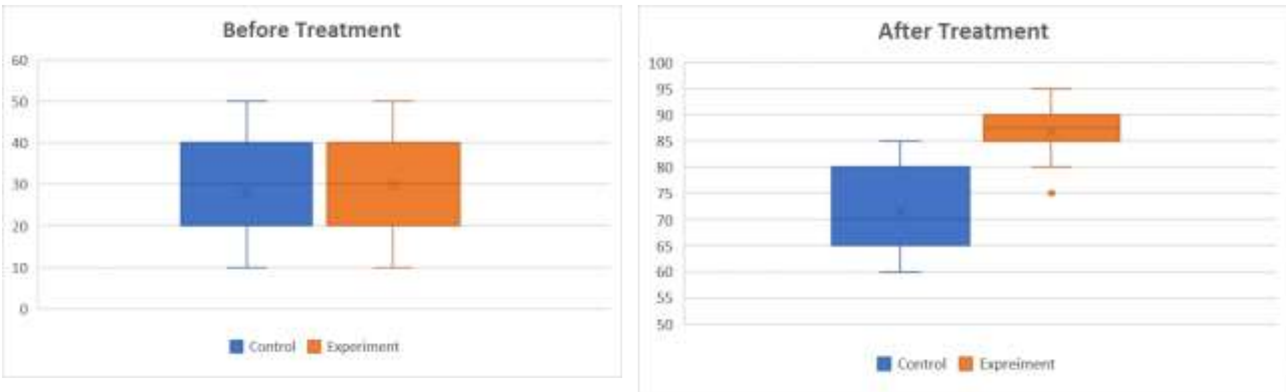

Fig. 7. Distribution data of problem-solving skill of the student in the control and experiment class

Figure 7 compares the two groups' problems solving data distribution before and after treatment. The line in the middle of the box plot for the experimental group is almost the same as the control group before treatment. However, it is higher than the control group after the treatment. It means the students who had been taught using mobile game education learning had a higher median score after treatment. Therefore, the average score of students' problems solving in the treatment group is higher than in the control group. Besides, the box plots for the experimental group are almost as long as the control group before and after the treatment. Hence, the problems solving skills scores are spread out among students in the two groups. All the lines in the middle of the box plots are close to the centre of the box, which means the distribution of scores has no slight skew at all.

3.2.1 Students' problems solving skills in experimental group

Based on the calculation results in Table 8, it was found that tabs t_{abs} = 55,934 > $t_{(0,025:104)}$ = 1.98304. Thus, a null hypothesis was rejected.

Table 8
T-test in the experiment class

	Mean	Std. Deviation	Std. Error Mean	t	df	Sig (2-tailed)
PS_post-PS_pre	70.587	9.879	1.118	55,934	52	0,000

Thus, there was a significant difference in the average score of students' problem-solving skills in the experimental group before and after treatment. It was evidenced that the probability score (sig.) was 0.000 < 0.05, so the null hypothesis was rejected. Therefore, there was a significant effect of the mobile game-based learning used in improving the students' problems solving on the learning material of algorithm and programming.

Based on the calculation results in Table 9, it was found that tabs t_{abs} = 43,987> $t_{(0,025:104)}$ = 1.98304. Thus, a null hypothesis was rejected.

Table 9
T-test in the control class

	Mean	Std. Deviation	Std. Error Mean	t	df	Sig (2-tailed)
PS_post-PS_pre	62.897	11.879	1.245	43,987	50	0,000

Thus, there was a significant difference in the average score of students' problem-solving skills in the experimental group before and after treatment. It was evidenced that the probability score (sig.) was 0.000 < 0.05, so the null hypothesis was rejected. Therefore, there was a significant effect of non the mobile game-based learning used in improving the students' problems solving on the learning material of the algorithm and programming.

3.3 Discussion

The game development life cycle is used to create digital games as a problem-solving-based learning medium, which results in considerable increases in student engagement and motivation. In this study, we used a systematic approach that included stages such as analysis, design, development, testing and launch, as proposed by Khaldi *et al.,* [15] who emphasized the importance of a structured approach in developing educational games to ensure the quality and relevance of the content delivered. At the planning and design stages for game mechanics, narrative and educational content. Sandí-Delgado *et al.*, [16] emphasized the significance of this phase in laying a solid foundation for the game. The study produced a detailed design paper and prototype to represent game mechanics and educational interactions. This strategy is consistent with the findings of Kubota *et al.,* [17] who found that extensive pre-production planning considerably minimizes development risks and enhances the quality of instructional games.

The development process using the Game Development Life Cycle offers a clear framework for assuring game quality. Othman *et al.,* [18] and Sinana *et al.,* [19] discovered that incorporating students in the game development process not only enhances learning results but also provides them with significant technical skills. In the study, alpha testing with a small group of users effectively discovered several functional difficulties, which were subsequently addressed before the final launch.

The findings of this study revealed that the digital games developed were effective in increasing student involvement in the learning process. This is consistent with the research conducted by Lytle *et al.,* [20], which found that games may provide dynamic and enjoyable learning experiences, allowing students to actively participate in solving complex problems. The use of games can also improve students' visual literacy skills. This is in line with the opinion expressed by Prameswari *et al.,* [21]. Other research by Zaric *et al.,* [22] demonstrated that game components such as challenges and rewards might boost students' intrinsic motivation to learn.

The efficacy of UEQ in capturing user experiences in educational games has been extensively documented. Lasawali *et al.,* [23] used UEQ to evaluate a language-learning game and discovered that the questionnaire accurately indicated game design strengths and areas for development. Our research supports these findings, as UEQ gave thorough feedback that guided incremental modifications to our game. Similarly, Sabukunze *et al.,* [24] in his study used UEQ to assess a mathematics learning game for secondary school students and discovered that high appeal and stimulation scores were associated with better learning outcomes. Our findings align with this, indicating that well-designed educational games can improve student engagement and learning at all levels of education.

4. Conclusion

The implementation of the Game Development Life Cycle (GDLC) in the development of educational games for college students has proven to be a useful framework for ensuring high-quality results. We can create engaging and instructive games by matching game content with educational aims, using agile development processes, stressing user experience and providing post-launch assistance. A comparison with current studies highlights the need for a systematic and iterative approach in game development, indicating that GDLC is a reliable methodology for developing effective educational games.

Based on the research results obtained, future research could explore the integration of digital educational games with new technologies such as augmented reality (AR) or virtual reality (VR) to further increase interactivity and engagement. Additionally, longitudinal studies could be conducted to assess the ongoing impact of these games on students' problem-solving and critical thinking skills over a longer period of time. Expanding the scope of research to cover diverse educational environments, such as universities or different school levels, could provide insight into the adaptability and scalability of the games being developed. Another direction is to investigate personalized learning features, leveraging artificial intelligence (AI) to adapt game content to each student's learning needs and pace.

The adoption of digital educational games as learning media can have far-reaching implications for higher education. By fostering active learning, critical thinking and problem-solving skills, these games align with 21st-century education goals, preparing students for complex real-world challenges. On a broader scale, integrating such games into traditional curricula can reduce the monotony of conventional learning methods, making education more inclusive and accessible to diverse learner profiles. Furthermore, this research underscores the potential of gamified learning to reshape pedagogical practices, encouraging educators to embrace technology as a tool for promoting creativity and engagement. Beyond the classroom, this approach could inspire innovations in professional training programs and lifelong learning initiatives.

To further refine the developed educational game, enhanced user feedback mechanisms should be implemented. This could include real-time analytics to monitor user interactions, pinpoint areas where students struggle and provide immediate, adaptive feedback. Incorporating a feedback loop within the game itself, such as surveys, in-game prompts or post-level reflections, would enable developers to collect qualitative insights directly from users. Additionally, a collaborative feedback system involving educators and peers could foster a community-driven approach to continuous improvement. By leveraging advanced feedback mechanisms, the game's usability, effectiveness and alignment with pedagogical goals can be consistently optimized.

Acknowledgment
This research can be carried out with funding for Fundamental Research by the Directorate General of Higher Education, Ministry of Education, Culture and Higher Education, Republic of Indonesia, under contract number 045/LL10/PG.AK/2024, 12/PRJ/II.3.AU/F/7/2024. The research team extends gratitude to the Universitas Muhammadiyah Riau and PP Muhammadiyah for their cooperation in terms of access and facilities.

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