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Development of Finite State Machine Computational Model for Dynamic Difficulty in an Educational Platformer Video Game

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ABSTRACT

This research aims to address the issue of static and unengaging educational history games for players with diverse skill levels. To this end, a 2D platformer game titled "Parahyangan" was developed, implementing a Dynamic Difficulty Adjustment (DDA) system based on a Finite State Machine (FSM), which allows the difficulty level to adapt to the player's performance. Using the Game Development Life Cycle (GDLC) methodology, the game was designed and quantitatively tested through a User Acceptance Test (UAT) with 85 respondents. The analysis shows that the game was well-received, falling into the "Good" category with a total satisfaction score of 77.55%. The core DDA feature was proven to be functional and well-accepted by the players. The user interface was identified as a major strength, while level progression was noted as an area for improvement. It is concluded that the implementation of DDA using an FSM is an effective solution for creating a more personalized, engaging, and sustainable learning medium for history that maintains player involvement.

Keywords: Dynamic Difficulty Adjustment, Educational Games, Finite State Machine, Player Experience, 2D Platformer.

1. INTRODUCTION

In the digital era, video games have evolved from mere entertainment media into potential educational tools, proven to enhance cognitive abilities such as working memory and impulse control [1]. This potential is particularly relevant in the Indonesian educational context, where games can be utilized to increase interest in local history and culture, a challenge identified in several previous studies [2], [3]. However, the development of educational games faces a significant challenge in balancing educational content with engaging gameplay. A game that is too educational risks being boring, while one that is too focused on entertainment may fail to deliver its message effectively.

Most prior research has focused on developing games with static difficulty levels [2], [4], which overlook the varying skill levels among players. This can lead to frustration for novice players or boredom for expert players, causing the educational message to be ineffectively conveyed. To address this issue, a system that can dynamically adjust challenges is needed. This study proposes the development of a 2D platformer game with an Indonesian history theme, implementing a Finite State Machine (FSM) computational model to create a Dynamic Difficulty Adjustment

(DDA) mechanism. The objectives of this research are (1) to implement an FSM model to build a functional and adaptive DDA system based on player actions, and (2) to produce a 2D platformer game that balances education and gameplay, and to measure its acceptance level. Through this approach, the research aims to create a more personalized and effective learning experience.

2. METHODOLGY

This section aims to provide the explanation of the methodologies used in the creation of the research

2.1 MATERIAL AND METHODS

This research employed a quantitative approach using the Game Development Life Cycle (GDLC) methodology. The research flow included several main stages: initiation, pre-production, production, testing (alpha and beta), and release, allowing for an iterative process of refinement based on feedback [5].

The core system of the game is the Dynamic Difficulty Adjustment (DDA) mechanism, built using the Finite State Machine (FSM) computational model. The FSM is used to manage transitions between three difficulty levels: 'Normal', 'Hard', and 'Very Hard'. These transitions are triggered by player performance, measured by the number of enemies defeated within a level segment. If a player defeats a predetermined number of enemies (e.g., $\geq$ 3) before reaching a checkpoint, the difficulty level increases to the next state. This logic ensures that the game's challenge dynamically adapts to the user's playstyle, whether passive or aggressive. The FSM workflow for the DDA system is illustrated in FIGURE 1.

The game was developed using the Unity engine. The DDA was implemented via a C# script that managed the “currentDifficulty” variable (as the FSM state) and “enemiesKilledSinceCheckpoint” (as the transition trigger). In addition to DDA, other key features included a character movement system, basic combat mechanics, and level design that supports dual playstyles (aggressive or passive). Educational history content was integrated through trivia panels that appear at each checkpoint.

Data was collected through a User Acceptance Test (UAT) distributed to 85 respondents from an online gaming community. The UAT questionnaire consisted of 11 questions measuring player satisfaction with functionality, gameplay, and the DDA feature using a 4-point Likert scale. Data analysis was performed by calculating the percentage of satisfaction for each question and overall. Additionally, a pre-test and post-test method was used to measure the increase in players' knowledge of the historical material presented in the game.

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FIGURE 1. FSM Flowchart of the DDA System

3. RESULTS AND DISCUSSION

The testing phase was divided into two parts: alpha testing by the developer and beta testing (UAT) by end-users. Alpha testing confirmed that all core functionalities, such as the UI, player controls, combat system, and DDA mechanism, performed as designed without critical errors.

From the 85 respondents who participated in the UAT, the data was analyzed to measure game acceptance. The overall satisfaction rate reached **77.55%**, which falls into the **"Good"** category. This result indicates that the "Parahyangan" game was generally well-received by its target audience. A summary of the response distribution from all questions can be seen in FIGURE 2.

A deeper analysis of specific questions revealed that the core DDA feature functioned and was well-received. Questions regarding the change in difficulty after defeating enemies (Questions 10 and 11) received satisfaction scores of 75% and 76.21%, respectively. This validates that the FSM implementation for DDA successfully created an adaptive experience that was perceptible to the players.

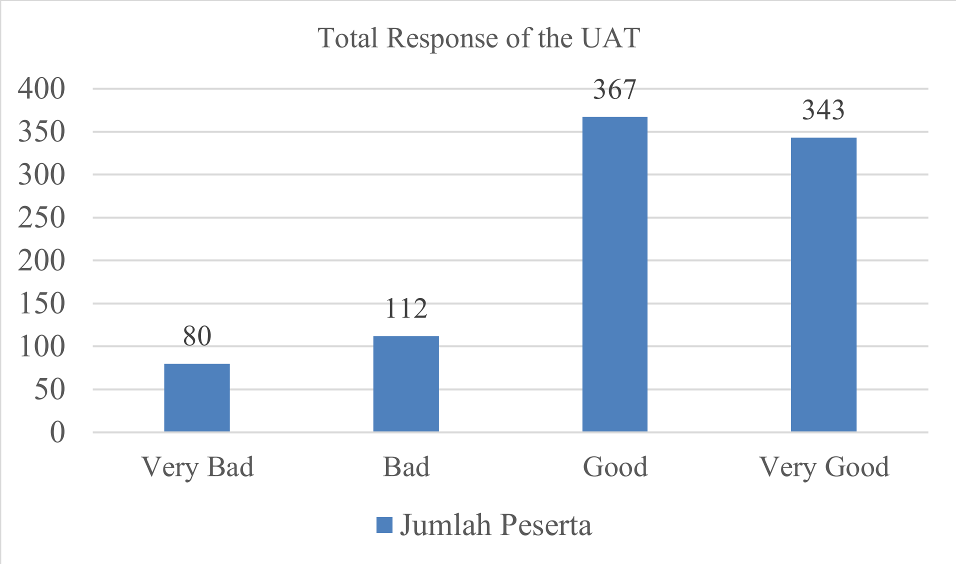

FIGURE 2. Total Response of the User Acceptance Test

The aspect with the highest satisfaction was level progression (80.19%), indicating that the flow and design of the levels were considered intuitive and well-paced. Meanwhile, the aspect with the lowest score was the visual appeal of the main menu (74.09%), suggesting room for improvement in the user interface aesthetics. The results are summarized in TABLE 1.

TABLE 1. Summary of UAT Satisfaction Percentages per Aspect

Aspect Testing	Related Questions	Satisfaction Percentages
Application Functionality	1	79,88%
UI Functionality and Appearance	2,3	75,92%
Player Controls and Mechanics	4,5,6,7	76,12%
Level Progression and Savepoint	8,9	79,12%
DDA Functionality	10,11	75,61%
Overall Average	All	77,55%

To measure educational effectiveness, a pre-test and post-test were conducted. The results showed a very significant increase in player knowledge. The average player score jumped from 36.83% in the pre-test to 94.15% in the post-test. This improvement proves that the educational content integrated into the gameplay was effectively absorbed by the players.

4. CONCLUSION

Based on the research results, it can be concluded that the implementation of a Finite State Machine (FSM) computational model was successfully used to create a functional and well-received Dynamic Difficulty Adjustment (DDA) mechanism in

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an educational history game. The developed 2D platformer game, "Parahyangan," proved capable of balancing educational elements with engaging gameplay, validated by a user acceptance rate of 77.55% ("Good" category) and a significant increase in players' historical knowledge. This finding demonstrates that FSM-based DDA is an effective solution for creating a more personal, adaptive, and engaging learning medium, thereby maximizing the potential of video games as an educational tool.

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REFERENCES

[1] B. Chaarani, J. Ortigara, D. Yuan, H. Loso, A. Potter, and H. P. Garavan, "Association of Video Gaming with Cognitive Performance among Children," *JAMA Network Open*, vol. 5, no. 10, p. e2235721, Oct. 2022.

[2] S. Sintaro, R. Ramdani, and S. Samsugi, "Rancang Bangun Game Edukasi Tempat Bersejarah di Indonesia," *Jurnal Informatika dan Rekayasa Perangkat Lunak*, vol. 1, no. 1, pp. 10–18, 2020.

[3] A. A. Saputra, F. N. Putra, and R. D. R. Yusron, "Pembuatan Game Edukasi Pengenalan Kebudayaan Indonesia Menggunakan Metode Game Development Life Cycle (GDLC) Berbasis Android," *JACIS: Journal Automation Computer Information System*, vol. 2, no. 1, pp. 31–38, 2022.

[4] Y. Akbar and M. F. Al Ammaar, "2D Platformer Game Prototype on Indonesian History Using Scratch," *International Journal Software Engineering and Computer Science (IJSECS)*, vol. 4, no. 3, pp. 1066–1076, 2024.

[5] M. R. Siregar and Nelmiawati, "Game 3D ‘Lawan Narkoba’ Menggunakan Metode Game Development Life Cycle (GDLC)," *Journal of Applied Multimedia and Networking (JAMN)*, vol. 4, no. 1, pp. 38-45, 2020.

[6] A. E. Adeniyi, et al., "Development of Two Dimension (2D) Game Engine with Finite State Machine (FSM) Based Artificial Intelligence (AI) Subsystem," *Procedia Computer Science*, vol. 235, pp. 2996–3006, 2024

[7] A. M. Rumakey, J. D. Irawan, and A. Wahid, "Pembuatan Game 2D ‘Escape Plan’ dengan Metode Finite State Machine," *Jurnal Mahasiswa Teknik Informatika*, vol. 4, no. 2, pp. 839-847, 2020.

[8] A. Li, I. Chai, and K.-W. Ng, "Dynamic Difficulty Adjustment in Video Games for Encouraging Physical Exercise: A Review and Theoretical Framework," in *Proceedings of the 2nd International Conference on Public Health, Social Science and Welfare (ICOPHSOW 2022)*, 2023, pp. 113–121. http://www.as.ttu.edu/kairos/2.1/features /browning/index. Html. (Accessed: 7 November 2000).

[9] R. Y. Ariyana, E. Susanti, M. R. Ath-Thaariq, and R. Apriadi, "Penerapan Metode Game Devlopment Life Cycle (GDLC) pada Pengembangan Game Motif Batik Khas Yogyakarta," *INSOLOGI: Jurnal Sains dan Teknologi*, vol. 1, no. 6, pp. 796–807, 2022.

[10] V. Erb, S. Lee, and Y. Y. Doh, "Player-Character Relationship and Game Satisfaction in Narrative Game: Focus on Player Experience of Character Switch in The Last of Us Part II," *Frontiers in Psychology*, vol. 12, 2021.
[11] A. T. Bayrak, "Compassionate Game Design: A Holistic Perspective for a Player-centric Game Design Paradigm for Games4health," in *IARIA*, 2020, pp. 21–27.
[12] N. Herlina, "Rekonstruksi Sejarah Kerajaan Sunda," *Kabuyutan: Jurnal Kajian Ilmu Sosial dan Humaniora Berbasis Kearifan Lokal*, vol. 3, no. 3, 2024.
[13] Z. Setiawan, "Sejarah Sosial Politik Kerajaan Majapahit," *Jurnal Lanskap Politik*, vol. 1, no. 1, 2022.
[14] D. Y. Wahyudi, A. A. Munandar, and T. I. Setyani, "The Shiva-Buddhist Concept in the Temple of Singhasari-Majapahit Periods," *International Review of Humanities Studies*, vol. 6, no. 2, 2021.
[15] D. Prayoga, L. Rusdiana, and F. Yedithia, "Pengembangan Game 2D Platformer 'Virus Must Die' Berbasis Android Menggunakan Unity," *Jurnal Pendidikan Fisika dan Terapan*, vol. 4, no. 1, 2022.

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