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DESIGN OF A SCIENCE LITERACY ROLE-PLAYING GAME (RPG) ON THE PROBLEM OF ENVIRONMENTAL POLLUTION

ARIE WIDYA MURNI[1], S. SURYANTI[1,*],
NADI SUPRAPTO[1], WAHONO WIDODO[1], WIRYANTO[1],
NOVARIA LAILATUL JANNAH[1], AMADHILA ELINA PENEHAFO[2]

[1]Universitas Negeri Surabaya, Surabaya, Indonesia
[2]Namibia College of Open Learning, Namibia
*Corresponding Author: suryanti@unesa.ac.id

Abstract

This study attempts to create a science literacy-based game using an RPG method to highlight the issues of environmental pollution. A DBR approach is followed, where needs assessment, design formulation, iterative refinement, and the review by media experts have been conducted. Results from validation reveal that the game has validity and is fit to be implemented for interactivity in education. Because of the results of the validation test showed that this game has the potential to make students more interested in learning processes, and to increase their understanding regarding environmental pollution issues. Other expected positive impacts include increased scientific literacy and increased environmental awareness of the students. The other future work recommended is a direct implementation test with real students in terms of how far the game can help students' understanding and awareness in a formal learning environment.

Keywords: Environmental pollution, Game design, Role-playing game (RPG), Science literacy.

1. Introduction

The design of a science literacy-based game using a Role-Playing Game (RPG) approach is an innovative strategy in education, especially at the elementary school level. Science literacy is very important for building scientific understanding and critical thinking skills from an early age. However, students often find some problems in connecting abstract thoughts of science to concrete reality, particularly about the global issue of the scientist facing problems related to pollution. This approach lets students, through RPG, gain interactive knowledge through practical training in such a way that it will better connect scientific knowledge with real situations, enhances learning motivation, and the capability for analysis to solve environmental problems [1-3].

Previous findings suggest that educational games also those designed as RPGs-can be very effective at improving science literacy and student engagement. Using RPG-based educational games helped students to develop a realistic view on the outcomes of pollution and how actions may affect the environment [4]. The narrative elements in RPGs provide a deeper learning context, while simulations help students develop critical thinking skills related to global sustainability issues and health [5, 6]. In addition, this game also enhances students' decision-making skills in the context of the environment [7, 8].

The aim of this research is to design a science literacy-based game using RPG, focusing on the issue of environmental pollution. The originality of this investigation is manifold: the integration of scientific literacy and RPG mechanics that aim to address specific challenges regarding environmental pollution; the problem-solving simulation relevant to real-life scenarios faced by the students themselves; and an engaging methodology whereby the participation of the students in the educational process is maximized and deepened in respect to environmental accountability.

2. Literature Review

Game design in educational games is necessary, which may be supported by attractive characters and storylines. A well-designed game can lead to improved motivation and engagement in learning for the students [3, 9]. Mechanical elements such as challenges and rewards also contribute to the effectiveness of learning [10, 11]. In addition, educational games enhance material understanding and information retention [12, 13], while environment-based simulation games help students understand the long-term impacts of pollution and encourage real actions for mitigation [14, 15].

RPGs are one type of game in which players can enact the role of any character within a predetermined situation, which enhances learning through experience. In this context, educational settings use RPGs in student participations through interactions and player choices along with the flow of the game process [2, 16]. RPGs also support problem-solving and collaboration skills [15, 17], where their narrative elements help students understand the impact of their actions in environmental scenarios [6, 18]. Therefore, RPG is effective in enhancing science literacy and environmental awareness [7, 19].

Science literacy is very important for students to understand and apply scientific concepts in everyday life. Educational games have been proven effective in

enhancing science literacy, particularly related to environmental issues [17, 20]. Scientific literacy-based games enable learners to connect theoretical ideas with real-world experiences, thereby facilitating learning [5, 7]. This model also allows students to develop awareness about the effects of pollution and therefore enables them to tackle future global challenges more effectively [3, 21].

Environmental pollution is a critical concern and a factor in the deterioration of human quality of life. The detrimental of pollution on air, soil, and water are depicted in Fig. 1, where ecosystems are visibly disrupted by smog, contaminated soil, and polluted water.

Fig. 1. Environmental pollution (a) air, (b) water, (c) soil.

In addition to causing respiratory illnesses, this pollution damages important natural resources, disrupts agriculture, and jeopardizes sustainable development. Figure 1 shows that pollution poses a serious threat to public health and environmental conservation initiatives due to its long-term impact on regional ecosystems and global climate patterns. Serious educational games on pollution raise greater awareness among students and involve them in attempts to limit the impact of pollution [20, 21]. The playing of intense simulation games allows students to understand the long-term effects of their choices concerning the environment [4, 5]. If the games are designed to include aspects such as pollution, then the learners will gain specific information on environmental conservation and resource management [22, 23]. This experience is quite important because students will grow into lives with numerous responsibilities and environmentally-based awareness [7, 17].

3.Method

This research uses a Design Based Research approach. (DBR). The stages in DBR include: (i) needs analysis, (ii) design development, (iii) iteration, and (iv) reflection. A needs analysis is conducted to address the lack of effective learning media in enhancing science literacy related to environmental pollution at the elementary school level, where there are still few resources that specifically integrate concepts with RPG-based science literacy games about environmental pollution issues. Therefore, a science literacy-based game design with RPG elements was created to serve as a solution to the existing gaps in learning media, with the hope of preparing students to become more responsible individuals who are aware of their environment. This research includes validation testing by media experts to ensure that the developed game is valid and suitable for use as an effective learning aid.

4. Results and Discussion

This is because educational challenges at an elementary school level require the teaching of science to be connected with real-life experiences. In this regard, development of science literacy-based RPG media is very much relevant. It was revealed from the needs analysis conducted that the understanding of the students about global issues, such as environmental pollution, is still very limited. Therefore, media that can provide interactive and applicable learning experiences, as well as enhance student motivation and engagement, is essential. Through the RPG approach, it is hoped that students can be more active in the learning process and can connect scientific knowledge with real-life situations, so that students' science literacy can develop well.

The plot in the science literacy-based RPG game that has been designed can be seen in Fig. 2, the game flowchart diagram. This diagram illustrates the steps and interactions undertaken by players in facing various challenges related to environmental pollution issues. The flowchart represents every step of the game, and it starts with the players in the character selection, then it goes through the introduction of the challenges, and finally ends in the players' identification and resolution of problems posed by pollution. This planned learning process is targeted to make the students acquire a combined and detailed vision of the action consequences of our planet environment.

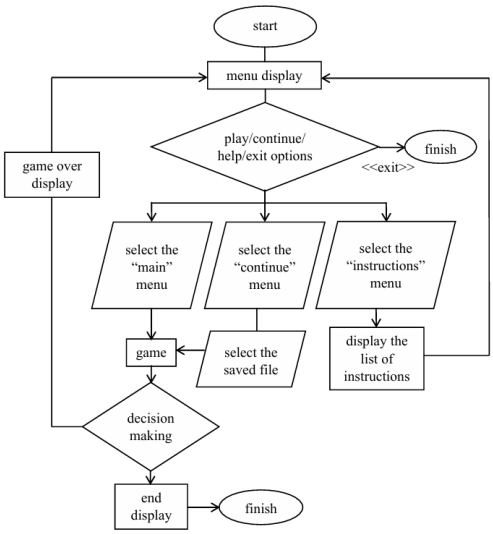

Fig. 2. Game flowchart diagram.

Figure 2 the game flowchart diagram depicts the flow of the game from a science literacy-based RPG. The flow of the game begins from the menu screen whereby players can choose one of several options in front of them play, continue a saved game, view instructions, or exit the game. Flowchart menu description as follows: (i) startup: the game starts by displaying the main menu; (ii) menu display: options like play, continue, help/ instructions, and exit are provided to the players; (iii) play options: the game will start from the beginning, continue options: the game resumes from the saved file, instructions options: a list of instructions will

appear, exit options: the game ends; (iv) game: the game starts after the players has chosen either "play" or "continue"; (v) decision making: during gameplay, participants will encounter instances that necessitate decision-making within the game; (vi) game over: the game is over when the player has made their final decisions and the game's terminal display has been presented.

The results of the development of this medium include the visualization of the product, shown in the screenshot of Fig. 3, which portrays the environmental pollution map.

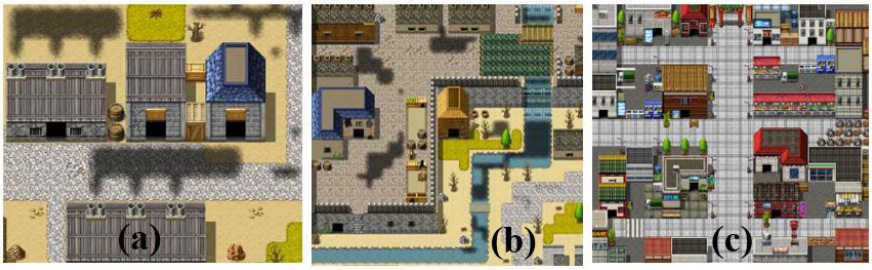

Fig. 3. Map environmental pollution (a) air, (b) water, (c) soil.

Figure 3 shows a screenshot of an environmental pollution map, where there is an air pollution map, a water pollution map, and a soil pollution map. These maps present a graphical representation of the areas affected by different forms of pollution. The air pollution map depicts the distribution or pattern in the atmosphere; however, the water pollution map shows where water bodies are contaminated. On the other hand, soil contamination maps show areas contaminated with toxic waste and hazardous chemicals for environmental conservation planning. This product will involve a set of attractive and colourful characters, scenes, and interactives to make environmental pollution topics more understandable to the students. It is expected that the materials produced will catch the students' attention and raise their willingness to learn about active participation in gaming activities.

Iterative phase of this media design involves various critiques by media experts for enhancing the overall quality of the game. It includes modification of the visual presentation, refining gameplay, and incorporating challenges which are much related to the everyday lives of the students. The hope is that the produced product can meet the ideal learning needs, even though it is currently still in the development stage and requires more evaluation from end users. The involvement of media experts has helped in creating better products, but further testing is needed to ensure the effectiveness of these media in enhancing science literacy.

Reflections from the design phase suggest that, in as much as many improvements had been made on the product, more development opportunities still existed. Information obtained from feedback early users provided important insights concerning the improvement need areas, which pertain to the difficulty level of the game and the need for an enhanced interactive engagement. By taking that feedback into account, further development is expected to optimize this media so that it meets the expectations and needs of the students.

The development of this science literacy-based RPG media refers to constructivist learning theory, which emphasizes the importance of active experience in the learning process. Educational games, such as role-playing games (RPGs), can create an engaging and interactive environment that facilitates students' comprehension of scientific principles [23]. In this instance, the media created is intended to improve students' grasp of environmental pollution topics and their relevance to daily life. While there are improvements in the various developed products based on the insights of media specialists and students, some shortcomings still need to be overcome. These are a limited variety in missions and a need to enhance interactivity. On one hand, increased evidence points out that high interactivity can lead to great improvement in student participation and provoke their curiosity [24, 25]. In this regard, it truly unlocks the possibilities of the medium to engage the learners and allow their further participation in the learning process. Thus, it can also be regarded as a tool that can effectively improve academic performances [26, 27]. Finally, this study adds new information as reported elsewhere [28-30].

5. Conclusion

This research uses the RPG method to design a science literacy-based game about environmental pollution problems. This game has been tested by media experts to be suitable for interactive learning. The results show the developed game has great potential in increasing students' interest and understanding of issues related to the environment. Other positive effects include an increase in students' science literacy and environmental awareness. Further research recommends live trials with students to gauge the effectiveness of the game in a formal context.

References

1. Abeele, M.M.V.; Antheunis, M.L.; and Schouten, A.P. (2016). The effect of mobile messaging during a conversation on impression formation and interaction quality. *Computers in Human Behaviour*, 62, 562-569.
2. Yu, Z.; Gao, M.; and Wang, L. (2021). The effect of educational games on learning outcomes, student motivation, engagement and satisfaction. *Journal of Educational Computing Research*, 59(3), 522-546.
3. Plass, J.L.; Homer, B.D.; and Kinzer, C.K. (2015). Foundations of game-based learning. *Educational Psychologist*, 50(4), 258-283.
4. Arnab, S.; Lim, T.; Carvalho, M.B.; Bellotti, F.; De Freitas, S.; Louchart, S.; and De Gloria, A. (2015). Mapping learning and game mechanics for serious games analysis. *British Journal of Educational Technology*, 46(2), 391-411.
5. Angelelli, C.V.; de Campos Ribeiro, G.M.; Severino, M.R.; Johnstone, E.; Borzenkova, G.; and da Silva, D.C.O. (2023). Developing critical thinking skills through gamification. *Thinking Skills and Creativity*, 49, 101354.
6. Deta, U.A.; Arika, A.; Lentika, D.L.; Al Lathifah, S.A.S.; Suliyanah, S.; Admoko, S.; and Suprapto, N. (2021). Research trend of socio scientific issues (SSI) in physics learning through bibliometric analysis in 2011-2020 using scopus database and the contribution of Indonesia. *Journal of Science Education Research*, 7(4), 682-692.

7. Widodo, W.; Sudibyo, E.; Suryanti; Sari, D.A.P.; Inzanah, I.; Setiawan. B. (2020). The effectiveness of gadget-based interactive multimedia in improving generation zâ€™ s scientific literacy. *Indonesian Journal of Science Education*, 9(2), 248-256.
8. Kristiani, A.; Wahyuni, D.; and Wahyuni, S. (2022). Interactive learning media development articulate storyline to improve science literacy capabilities of junior high school students. *Berkala Ilmiah Pendidikan Fisika*, 10(2), 186.
9. Ibrahim, R.; and Jaafar, A. (2009). Educational games (EG) design framework: Combination of game design, pedagogy and content modeling. *Proceedings of the* 2009 *International Conference on Electrical Engineering and Informatics* (*ICEEI*), Bangi, Malaysia, 293-298.
10. Subhash, S.; and Cudney, E.A. (2018). Gamified learning in higher education: A systematic review of the literature. *Computers in human behavior*, 87, 192-206.
11. Rizki, I.A.; Saphira, H.V.; Alfarizy,Y.; Saputri, A.D.; Ramadani, R.; and Suprapto, N. (2023). Adventuring physics: Integration of adventure game and augmented reality based on android in physics learning. *International Journal of Interactive Mobile Technologies*, 17(1), 4-21.
12. Buckley, P.; Doyle, E.; and Doyle, S. (2017). Game on! Students perceptions of gamified learning. *Journal of Educational Technology and Society*, 20(3), 1-10.
13. Sidek, S.F.; Yatim, M.H.M.; and Said, C. (2022). The design and validation of a tool to measure content validity of a computational thinking game-based learning module for tertiary educational students. *International Multidisciplinary Research Journal*, 4(1), 1-9.
14. Crookall, D. (2013). Climate change and simulation/gaming: Learning for survival. *Simulation and Gaming*, 44(2-3), 195-228.
15. Romero, M.; Usart, M.; and Ott, M. (2015). Can serious games contribute to developing and sustaining 21st century skills? *Games and Culture*, 10(2), 148-177.
16. Anggraeni, D.M.; Prahani, B.K.; Suprapto, N.; Shofiyah, N.; and Jatmiko, B. (2023). Systematic review of problem-based learning research in fostering critical thinking skills. *Thinking Skills and Creativity*, 49, 101334.
17. Zulfiqar, S.; Sarwar, B.; Aziz, S.; Ejaz Chandia, K.; and Khan, M.K. (2019). An analysis of influence of business simulation games on business school students' attitude and intention toward entrepreneurial activities. *Journal of Educational Computing Research*, 57(1), 106-130.
18. Yamada, F.M.; Ribeiro, T.; and Ghilardi-Lopes, N.P. (2019). Assessment of the prototype of an educational game on climate change and its effects on marine and coastal ecosystems. *Revista Brasileira de Informática na Educação*, 27(3), 01-31.
19. Janakiraman, S.; Watson, S.L.; and Watson, W.R. (2018). Using game-based learning to facilitate attitude change for environmental sustainability. *Journal of Education for Sustainable Development*, 12(2), 176-185.
20. Hutson, J.; Fulcher, B.; and Weber, J. (2022). Gamification in education: A study of design-based learning in operationalizing a game studio for serious games. *Journal of Intelligent Learning Systems and Applications*, 14(1), 115-131.

21. Staddon, R.V. (2023). Exploring higher education students perspectives on factors affecting use, attitudes and confidence with learning technologies. *International Journal of Instruction*, 16(2), 31-52.
22. Gee, J.P. (2003). What video games have to teach us about learning and literacy. *Computers in Entertainment* (*CIE*), 1(1), 20-20.
23. Lampropoulos, G.; Anastasiadis, T.; Siakas, K.; and In, L.E. (2019). Digital game-based learning in education: Significance of motivating, engaging and interactive learning environments. *Proceedings of the* 24th *International Conference on Software Process Improvement-Research into Education and Training* (*INSPIRE* 2019), Southampton, UK, 117-127.
24. Lee, N.; and Kim, B.S. (2021). International student engagement for sustainability of leisure participation: An integrated approach of means-end chain and acculturation. *Sustainability*, 13(8), 4507.
25. Huang, Y.M. (2019). Exploring students acceptance of educational computer games from the perspective of learning strategy. *Australasian Journal of Educational Technology*, 35(3), 132-149.
26. Li, M.C.; and Tsai, C.C. (2013). Game-based learning in science education: A review of relevant research. J*ournal of Science Education and Technology*, 22, 877-898.
27. Murni, A.W.; Suryanti, S.; and Suprapto, N. (2023). Use of bibliometric software to explore the relationship between scientific literacy and socio-scientific issues. *E3S Web of Conferences*, 450, 03009.
28. Glorifica, I. (2021). Media analysis of biology teaching book grade xii: A study based on science literation category. *Indonesian Journal of Educational Research and Technology*, 1(2), 17-22.
29. Susilawati, A.; Kustiawan, I.; Rochintaniawati, D.; Hasanah, L.; and Lim, Y. (2024). Light intensity distribution in the room using light dependent resistor: Through the engineering design process. *Indonesian Journal of Science and Technology*, 9(3), 679-708.
30. Susilawati, A.; Al-Obaidi, A.S.M.; Abduh, A.; Irwansyah, F.S.; and Nandiyanto, A.B.D. (2025). How to do research methodology: From literature review, bibliometric, step-by-step research stages, to practical examples in science and engineering education. *Indonesian Journal of Science and Technology*, 10(1), 1.