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Digital-Game Based Learning Innovation on POE: Constructing Student's Mental Models on Temperature Effect on Reaction Rate

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Abstract: The aim of this study is to identify how the POE learning integrated into D-GBL can construct student's mental models on temperature effect on reaction rate and the game design is created. This research is a part of the Research and Development (R&D) with Borg and Gall model. This study is focused on the third stage. The study began with collecting information, planning product, and prototype development. For product design, the study created mission and sub-missions to represent the POE steps, which are predicting, observing, and explaining. The information was collected from various literature reviews on D-GBL and mental model. For product design, mission and sub-missions were created to represent POE steps. Next, the prototype was developed in the form of a game design document. Students must answer various questions to complete these missions and sub-missions. If the answers are given incorrect, the game restart from the beginning of that mission. Therefore, D-GBL integrated in the POE model can construct students' mental models.

Keywords: Digital-game based learning; Mental model; POE; Reaction rate

Introduction

21st century learning offers various opportunities for students to participate in the learning process. Some of learning methods that teachers have used include cooperative learning (Agwu & Nmadu, 2023; Chophel & Norbu, 2021; Sibomana et al., 2021), problem based learning (Kasuga et al., 2022; Prastika et al., 2022; Stieff et al., 2012), and game based learning (da Silva Júnior et al., 2021; Fitriyana et al., 2020; Sousa Lima et al., 2019). Digital-game based learning is an interesting method that can be implemented, where elements of the games are integrated into education, creating an interactive, engaging, and not boring. Within D-GBL, concepts related to daily life are incorporated (Bayir, 2014). So, the game not only contain these concepts, but also relate them to the given phenomena, thus forming a coherent mental model.

A mental model is one of the abilities of students in problem-solving. The aim is to determine the action that are taken when problems are presented (Dauer et al., 2019; Riemer & Schrader, 2019). The mental models formed in students consist of interconnected concepts that develop as the student's learning experiences increase. Therefore, the games developed using an approach in learning but, the digital game that have been developed, especially about reaction rate, have not utilized a teaching approach capable constructing student's mental models. For example, the game develeloped by (Zubaidah & Muchtar, 2020) which still presents content in form of videos and execises for each subtopics. Another digital game developed by (Hafis et al., 2019) only provides the opportunity to manipulate factors that effects reaction rate, such as temperature and concentration.

The Predict-Observe- Explain (POE) learning can be integrated into digital games. POE learning is one of the

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inquiry- based learning methods that help student's construct concepts by themselves. Students predict the results of observations based on phenomenon. Then, they further observe the phenomena and connect them with their earlier predictions. In the end, they explain the concepts, thus forming a comprehensive mental model (Mamun et al., 2020; Wang & Wang, 2023).

Several studies have shown that the POE learning is effective to construct student's mental models. In addition, POE learning can overcome miscopcention compared to conventional learning and give effect on the change of mental model students (Jasdilla et al., 2019; Kibirige et al., 2014).

However, there is still no media available, such as D-GBL integrated on POE, especially in the concept of temperature effect on reaction rates. Therefore, the development of POE-based digital game prototyped aimed at constructing student's mental model about the effect of temperature on reaction rates

Method

This research using the Research and Development methods with Borg and Gall model. Out of the 10 stages in the Borg and Gall (Borg, 2014), the study is limited to the third stage, namely initial product development. The development stages of the Borg and Gall model can be seen in the Figure 1.

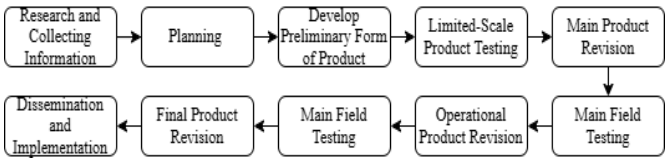

Figure 1. Borg and Gall Model

The study began with collecting information, planning product, and prototype development. The information was collected from various literature reviews on D-GBL and mental model. For product design, mission and sub-missions were created to represent POE steps. Next, the prototype was developed in the form of a game design document. The game design document contains several analyses, such as multiple representation of the content, guided questions, and game concepts.

To complete this mission and sub-missions, students are required to answer various questions. If the answers are given incorrect, the game will restart from the beginning of that mission. Therefore, D-GBL integrated in the POE model can construct students' mental models. From these three steps, the research questions focused on how the POE Learning approach is integrated into D-GBL to build students' mental models, what the game design and elements are presented in D-GBL, and what the challenges and opportunities arise in developing D-GBL.

Result and Discussion

Mental Model

The development of digital games aims to create a learning tool that can help students construct mental models independently. In an effort to build students' mental models, especially in the context of reaction rates, several learning models have been used, such as the cooperative learning approach. In this method, students are grouped and collaborate to discuss given problems. The goal is to ensure that each student has an equal opportunity in the learning process (Prastika et al., 2022; Taştan Kirik & Boz, 2012). In addition, a guided inquiry approach based on experiments can also be applied by teachers (Mirich et al., 2020; Murni et al., 2022; Van Brederode et al., 2020). Through this method, students can systematically develop concepts through experiments and answer directed questions that help identify each individual's understanding. To measure the mental models formed, teachers can use a diagnostic two-tier test, as done in the study by (Murni et al., 2022) where it was found that the inquiry learning model has a positive impact on building students' mental models compared to the control class that uses inquiry-based modules.

Digital-Game Based Learning

This approach, or D-GBL, has been shown to have a positive impact on building students' mental models, as demonstrated by the study by Hung et al., (2012) which stated that D-GBL effectively improves learning outcomes with the help of cognitive analysis tools. In addition, students are able to build mental models through relevant analogies with everyday situations (Coll, 2006) in understanding certain concepts, such as chemical equations (Le Maire et al., 2018). Integration of D-GBL can also be done in the form of modules (Osman & Lay, 2022) which allows students to visualize chemical concepts at the submicroscopic level (Fontana, 2020; Winter et al., 2016).

POE Learning in Digital-Game Based Learning

The POE learning involves the active involvement of students through discussion and experimentation (Guerrero et al., 2020). During the learning process, students have the opportunity to express their ideas, views, and reasons through group discussions in solving everyday problems. The goal is to encourage the formation of conceptual understanding in the learning process (Chen, 2022; Sengul, 2022). Sarıoğlan & Özkaya (2021) found that the implementation of POE learning in digital games can help students understand the causes

and effects of global warming in everyday life and produce products that describe the concepts acquired.

The use of the POE learning in digital games is one strategy to help students build mental models of abstract concepts. Through digital games, abstract concepts can be visually illustrated. For example, in a digital game, students will observe a video about reaction rates in HCl and $Na_2S_2O_3$ solutions at various temperatures. Through this video, students understand that the higher the temperature, the faster the reaction occurs in both solutions. However, in understanding chemical concepts, students do not rely solely on observation. They also need to be able to explain the reasons behind the observed concepts. Therefore, visualization of the concepts learned becomes important. In that digital game, animations that illustrate the movement of molecules when the solutions are mixed will be provided.

The POE learning is one form of inquiry-based learning that follows three steps: predict, observe, and explain. This is the sequence of the POE learning stages implemented in this game;

Predict

In the predict stage, a video demonstrate that related to the effect of temperature on reaction rate. Students will make predictions about possible outcomes and provide reasons based on their understanding (Fitriani et al., 2020). The predict stage can be seen in the Figure 2.

Figure 2. Predict Stage

The recorded video of the interaction between Magnesium and 1 M HCl solution at two different temperatures: 27°C and 50°C is observed by students. Through this video, students will predict at which temperature the reaction between the two solutions will occur rapidly.

Observe

In the observe stage, an experimental video will be presented to verify the accuracy of student's prediction an reasons (Nalkiran & Karamustafaoglu, 2020). The observe stage can be seen in the Figure 3.

Figure 3. Observe Stage

While watching of the video experiment of mixing magnesium an1 M HCl solution, the students record the duration required for each experiment and make conclusions about how temperature changes affect the reaction rate.

Explain

The final stage, explain, involves a graph about interaction between (.....) the explain step consists of a series of structured questions that guide students to discover concepts based on the videos. The observe stage can be seen in the Figure 4.

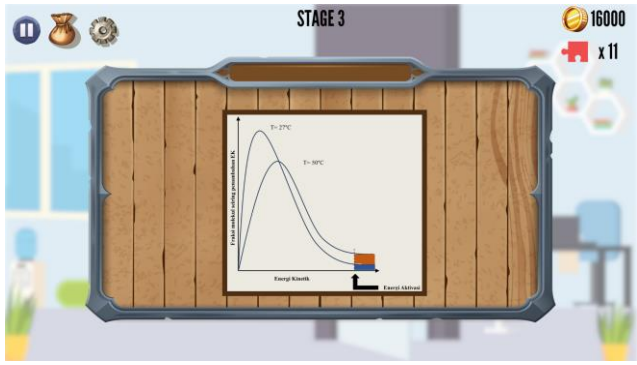

Figure 4. Explain Stage

The aim of this graph is to facilitate the students in connecting the effects of temperature changes on reaction rates and providing explanations based on the concept of collision theory.

Game Design

The game is developed as an application that can be downloaded from Playstore or Appstore, making it easily accessible for students. The game consists of one mission that is divided into two sub-missions. The mission and two sub-missions are related to the three stages of POE learning, where the mission (predict), sub-mission 1 (observe), and sub-mission 2 (explain) are

interconnected. The game flowchart is as follows in figure 5.

After receiving the mission, the students are asked to watch an experimental video as a requirement to continue the game, then start answering questions. If the students answer a question incorrectly, the game will automatically restart from the beginning of each mission.

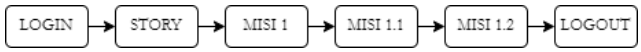

Figure 5. The Game Flowchart

This is intended to identify which concept is difficult and how many times it takes to obtain the correct answer. The one of mission is as follows :

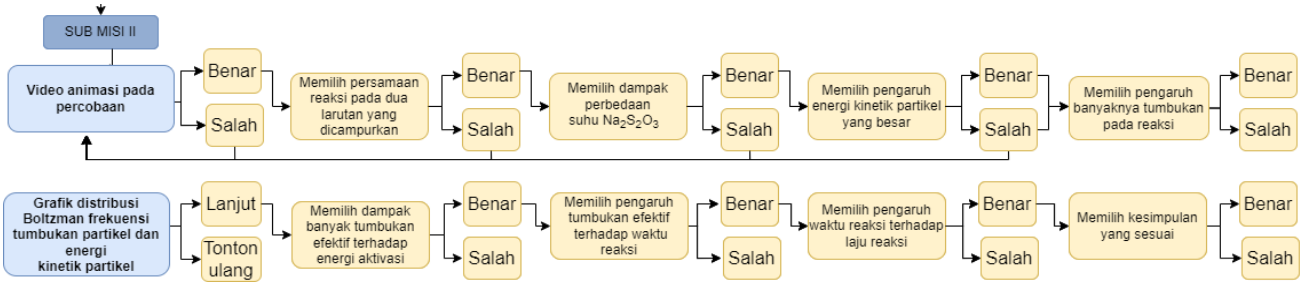

Figure 6. One of the Missions

On the game login page, there will be a cover display containing the game title, player profile, game rules, and mission options.

Figure 7. Login Page

Figure 8. Player Profile

Figure 8 shows the page for inputting data such as name and date on the login page. After inputting the data, the students will be directed to the player profile page (Figure 7), which contains the student's name, last login, number of logins, and other informations. In addition, there are three buttons in the upper left corner that function as setting, store, and profile.

One of the principles of game development is a storyline in the game. This is intended so that students can enjoy the game and train their memory while playing the game.

Figure 9. Storyline

In addition, there are other aspects, such as challenges that students deal with throughout the game. These challenges will be dealed with every time they move on to the next sub-mission. The challenges of the game can be seen in the Figure 10.

The difficulty level will increase as they enter sub-mission 2. This is because in sub-mission 2, the students have entered the explain learning stage. At this stage, the students' understanding begins to form until they obtain a complete mental model.

Figure 10. Challanges

Challenges and Opportunities

In developing this digital game, there are challenges and opportunities to be gained. The challenges faced are still a lack of understanding of how aspects of digital games can affect students in constructing mental models. This is due to the lack of research that examines digital games that can construct mental models, making it difficult to design effective and efficient games. On the other hand, the opportunities in developing this digital game are that digital games provide opportunities for students to overcome difficulties experienced during learning, such as material that is too dense and boring or material that is too difficult to understand (Al-Azawi et al., 2016). Combining elements in the game, such as challenges (Gupta, 2019; Hamari et al., 2016), reward (Fontana, 2020), and punishments, can complement POE-based digital games in creating an engaging and deep learning experience. In addition, digital games can provide visual representations of complex concepts.

Conclusion

Based on the results and discussions, digital game-based learning with a POE approach can construct students' mental models.

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Author Contributions

The main author, F.R., who contributed to the conceptual research, research design, methodology, prototype preparation. The second and third authors, W.W., and S.M., were involved in research as a reviewer on this article and provided suggestion in writing this article.

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Conflicts of Interest

The authors declare no conflict of interest

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