Exploring the Benefits of Chatbots Game-based Learning in Science Learning Outcomes and Motivation

Ching-Huei CHEN
Department of Industrial Education and Technology, National Changhua University of Education, Taiwan
chhchen@cc.ncue.edu.tw

Abstract: In this study, we aimed to assess the effectiveness of using Chatbot-assisted game-based learning to enhance science learning outcomes and motivation. A total of 202 seventh-grade students participated in the study and were randomly assigned to three groups: (1) Game only, (2) ChatbotGame, and (3) ChatbotGame with examples. The experimental groups received game-based learning with the assistance of Chatbot, either with or without examples, while the control group only received game-based learning without any Chatbot support. The results indicated that students in the ChatbotGame with examples group achieved significantly better learning outcomes compared to those in the Game only group. Moreover, students in both the ChatbotGame and ChatbotGame with examples groups reported significantly higher levels of perceived competence compared to the Game only group. Additionally, the data collected from learning analytics and interviews suggested that Chatbot-assisted game-based learning can effectively enhance students' intrinsic motivation and promote positive learning behaviors in the context of science education. These findings hold important implications for the design and implementation of Chatbots in game-based learning environments, as they have the potential to significantly improve students' learning outcomes and motivation.

Keywords: Chatbot, game-based learning, science learning, motivation, ChatGPT

1. Introduction

The rise of digital game-based learning (DGBL) in educational settings has been populated by its ability to boost student engagement, motivation, and learning performance, as evidenced by studies conducted by Clark et al. (2016). Nonetheless, creating effective DGBL environments poses challenges, as it necessitates careful consideration of factors like game mechanics, instructional design, and learning objectives, as highlighted by Cai et al. (2022). Moreover, without appropriate scaffolding during DGBL, students may become overly focused on game mechanics or engage in various non-learning behaviors, as warned by Chu et al. (2022).

As the product of artificial intelligent, virtual agents such as Chatbots have the capability to generate human-like responses in natural language conversations. Numerous studies have examined the effects of Chatbots on learning outcome, yet scant studies exploring its potentials in game-based learning (GBL). To fully unlock the advantages of Chatbots-assisted GBL, further research is necessary to gain a deeper understanding of the most effective design and implementation of such environments, while also addressing challenges related to overreliance on Chatbots and the importance of effective design and implementation.

2. Review of relevant literature

2.1 Digital game-based learning

Digital Game-Based Learning (DGBL) is an educational approach that employs games and digital technologies to enhance learning outcomes. It integrates game design principles like problem-solving and interactive engagement to make learning more enjoyable and increase motivation and knowledge retention among learners. Existing research has shown that DGBL can boost engagement, motivation, and knowledge transfer among learners (Westera, 2015). However, there are challenges associated with designing effective educational games that align with learning objectives (Ke, 2016). Some learners might not be interested in gaming or find it difficult to learn through this approach (Hao et al., 2019).

To overcome and address challenges faced in DGBL, artificial intelligence (AI) technology may offer alternated and optimal solutions in DGBL. For example, AI can analyze student gameplay behaviors to predict early knowledge or assess learned knowledge more accurately (Alonso-Fernández et al., 2020). Unlike traditional intelligent tutoring systems, AI can offer personalized feedback, pinpointing areas of mistakes, and suggesting alternative approaches (Alam, 2021). This advances the potential of DGBL in creating more effective and tailored learning experiences.

2.2 Chatbots

Chatbots utilized natural language processing techniques is becoming increasingly important in many fields because of its ability to process and analyze large amounts of data and perform complex tasks quickly and accurately. A recent noteworthy application of chatbots is ChatGPT, a language model developed by OpenAI, which has garnered significant attention and found use in diverse areas like customer service, education, and entertainment. By leveraging machine learning algorithms, ChatGPT generates responses based on patterns and relationships learned from extensive training data. As it continues to learn and improve from additional data and user feedback, this tool has the potential to revolutionize technology interactions, offering more personalized and engaging experiences for users (Hassani & Silva, 2023).

Although some studies have already demonstrated ChatGPT's effectiveness as a valuable reference and self-learning tool, further rigorous and empirical research is necessary to comprehensively assess its impact on student performance and behavior (Lo, 2023). The purpose of this study is to explore the effects of integrating ChatGPT in game-based learning on students' science learning outcomes and intrinsic motivation.

3. Methodology

3.1 Design and participants

A quasi-experimental study design was employed to answer the proposed research questions. A total of 202 seventh graders (103 male and 99 female) from nine classes in two different middle schools were recruited and randomly assigned to three treatment groups: (1) Game only, (2) ChatbotGame, and (3) ChatbotGame with examples.

3.2 ChatGPT-assisted game-based learning

The GPT coding application programming interface (API) with access to OpenAI's GPT language (gpt-3.5-turbo) model was used in this study. With this API, we can integrate the GPT language model into the game, allowing it to generate human-like language and respond to user input in a natural and coherent manner. The GPT coding API is an essential tool used to incorporate NLP capabilities into *Summon of Magicrystal*. GPT-assisted *Summon of Magicrystal* represents an exciting new approach to digital game–based learning that utilizes cutting-edge language processing technology to provide a more engaging, personalized, and effective learning experience for students. As shown in Figure 1, students

can click on Ask-AI for a conversation forum to pop-up so that they can ask questions. In addition to students initiating the questioning, the system also provide examples for them to ask questions.

Figure 1. ChatGPT with examples in Summon of Magicrystal

3.3 Instrument

3.3.1 Science learning outcomes

In order to evaluate the students' conceptual understanding in response to this study, a conceptual test was created by two experienced science teachers with 20 years of expertise. This test served as both a pretest and a posttest and comprised 16 multiple-choice questions centered on the concepts and principles addressed during the gameplay. The maximum score achievable on the test was 100. To ensure its reliability and validity, the questions underwent rigorous examination, revision, and validation by two other seventh-grade science teachers. Additionally, pilot testing with seventh-grade students was conducted. The Cronbach's alphas for the pretest and posttest were found to be 0.82 and 0.80, respectively, indicating good internal consistency and reliability of the test.

3.3.2 Learning motivation

The intrinsic motivation questionnaire utilized in this study was adapted from Deci and Ryan's (2000) instrument and consisted of 14 items, distributed across four subscales. These subscales were interest (four items, e.g., "I enjoyed playing this game very much"; Cronbach's alpha = .73), perceived competence (three items, e.g., "I think I am pretty good at this game"; Cronbach's alpha = .91), tension (three items, e.g., "I felt very tense while playing this game"; Cronbach's alpha = .87), and perceived value (four items, e.g., "I believe this game could be of some value to me"; Cronbach's alpha = .94). Using a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree), the students were asked to rate these items.

3.4 Procedure and data analyses

Participants were recruited from their respective classes according to the regulations of the university's institutional review board. The study lasted 2 weeks, with one 50-min session each day. The participants began by taking a multiple-choice conceptual pretest. Following that, the researchers informed the students about the study purposes, explained the game environment, and assigned each student a unique username and password. The students in the ChatbotGame and ChatbotGame with examples groups were informed of the capabilities of such functions in the gameplay. Toward the end of the gameplay, the participants completed a posttest and a web-based survey that included intrinsic motivation questionnaire. Analysis of covariance (ANCOVA) was performed to evaluate science

learning outcomes with a significance level of $p < 0.05$, and a t-test was used to assess intrinsic motivation. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS 11.0 for Windows).

4. Results

Effects on science learning outcomes and learning motivation

One-way ANCOVA was adopted to examine the three groups' science learning outcomes. The ANCOVA results revealed that after excluding the effects of the pretest scores, there was a significant difference between groups ($F = 5.94$, $p = 0.003$), indicating that the students had significantly different learning achievements as a result of using the different learning models. The posttest score of the ChatbotGame with examples group ($M = 49.06$) was significantly higher than the game only group ($M = 44.46$). This indicates that the students who used ChatbotGame with examples outperformed those who used the game alone.

One-way analysis of variance (ANOVA) was employed to explore the effects of the different gameplay modes on students' motivation. There was a significant difference in perceived competence among the three groups ($F = 3.69$; $p = 0.03$). The average perceived competence scores of the ChatbotGame with examples and ChatbotGame groups and the Game only group were 2.63, 2.54, and 2.21, respectively. While there was no significant difference among the three groups in terms of interest, tension, and value, the students in the ChatbotGame with examples and ChatbotGame groups reported higher perceived competency than those in the Game only group.

5. Discussion and conclusions

The purpose of this study was to examine the potential of AI-assisted GBL in terms of students' science learning outcomes and intrinsic motivation. In terms of the students' science learning outcomes, it was found that there was a significant difference between the ChatbotGame with examples and Game only groups. Those students learning with the assistance of examples provided by ChatbotGame outperformed those learning only within the game. The students learning without examples also did better than those who learned with only the game. To investigate the students' perceptions of the two different ChatbotGame modes further, some students in both groups were selected for in-depth interviews. Several students who had learned with examples provided by ChatbotGame pointed out that those examples helped direct their attention to relevant concepts and facilitated their gaming strategies. However without the examples, the students found that it was difficult to initiate questions because they had limited knowledge of the subject matter and were not sufficiently well-versed in the topic for them to come up with meaningful and relevant questions.

Overall, the use of Chatbots-assisted GBL has the potential to revolutionize education by creating personalized, adaptive, and engaging learning environments that meet the needs of every student. However, more research is needed to fully understand the potential of these technologies and to ensure that they are implemented in an ethical and responsible manner (Lo, 2023). Our study yields theoretical and practical implications for Chatbots-assisted DGBL. It theoretically incorporates ChatGPT into DGBL, providing insights into how learners' interactions with conversational agents help them strengthen their knowledge and revealing the capabilities of NLP to enable more conversational and interactive learning experiences. Practically, ChatGPT can be utilized as an intelligent assistant within DGBL, offering examples or explanations to help learners navigate challenging tasks or overcome obstacles. The examples can foster deeper understanding of complex concepts as well as enhance students' problem-solving abilities.

This study has several limitations that future research should address. The first concerns the transfer effect of Chatbots-assisted GBL. Future research could investigate, for

example, how ChatGPT can support the transfer of learning from game-based environments to real-world contexts. This includes exploring techniques to bridge the gap between virtual experiences and real-life applications, ensuring that the skills and knowledge acquired through DGBL can be effectively transferred and applied. A second area of future research concerns the effectiveness of ChatGPT in DGBL varies across different subject areas and age groups. Continued exploration in these areas can contribute to the development of more effective and engaging learning experiences for students.

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