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Plastic Island Game: A Digital Game for Facilitating Citizen Inquiry Pedagogy in School Science Education

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Abstract:
Promoting essential skills to fulfill 21st-century learning goals is undeniable. Using contextual issues as the topic for learning and citizen inquiry as a pedagogy can be considered an alternative approach for students learning in science to achieve their goals. In addition, active learning in a contextual issue, such as the environment, will give students benefits for meaningful learning. However, few technologies supported citizen inquiry learning with specific topics are available. Hence, developing technology for supporting citizen inquiry is beneficial for students and teachers. In designing the game, the researchers must focus on inquiry steps and involve socio- scientific issues to achieve meaningful learning. This paper focuses on implementing a digital game as technology to support citizen inquiry which aims to evaluate the game quality and assess pre-service science teachers' motivation and self-efficacy toward implementing citizen inquiry. Based on the results, the quality of the game categorizes as good, and pre-service teachers' motivation shows that intrinsic motivation outnumbers extrinsic motivation. At the same time, pre-service teachers' self-efficacy shows a good result, with mean scores exceeding three on a scale of 1 to 5. The findings imply that digital game technology can be used in teacher professional development, especially to train teachers or pre-service teachers in the inquiry or citizen inquiry context.

Keywords: Citizen inquiry, Inquiry-based learning, Digital game, Pedagogical application, Microplastic

1. Introduction

Learning science through inquiry is not a new thing anymore. As Chiang et al. (2014) mentioned, many countries incorporated inquiry learning in the range of K-12 education. However, the result of students' achievement in learning science is still below the standard line (PISA); a case in Indonesia's mean score for science performance is 396 below the OECD average, which is 489. In addition, (Paidi et al., 2020) also stated that students' cognitive achievement in Indonesian high school students is not satisfactory. The findings indicate worrisome results in learning and teaching science. This problem becomes a big issue considering the future aims of teaching and learning science. As mentioned in OECD in the following education outcome, the important thing for students is to achieve well-being by using meaningful learning (OECD, 2019). Mason et al. (2019) also explained that the future direction of education is appropriate pedagogy to foster the growth of an individual or person. One of the pedagogies for the future trend is citizen inquiry (Mason et al., 2019) which is scientific inquiry investigations involving the public's participation. Results show that socio-scientific issues implement in the citizen inquiry (McKercher et al., 2017; Sharples et al., 2017; Forrest et al., 2019).

Based on the previous study (Adita et al., 2021), one of the possible technologies is a digital game. The digital game has many advantages, such as improving student learning (Qian & Clark, 2016) and providing various educational experiences (Srisawasdi & Panjaburee, 2019). Therefore, using the digital game in learning science is an opportunity peculiarly to accommodate the digital native. In addition, integrating the digital game with inquiry pedagogy has been proven to affect students' achievement to transform the concept of science (Srisawasdi & Panjaburee, 2019). Importantly, using learning strategies such as inquiry in mobile based-learning was still low implemented from 2007-2016 (Chang & Hwang, 2019).

This study also stated that through digital games, the role of the teacher in conducting learning is still important. Therefore, in this study, the researchers develop a game that does not eliminate teacher existence. Also, the game can be integrated with the hands-on experiment activity in a practical laboratory if learning by doing and directly in the experiment is meaningful for students. The inquiry method embedded in this game involves several steps students need to accomplish the game. Although the researchers used the term citizen inquiry in this research, this did not engage public participants in this study. However, it is possible to do in the future direction.

In addition, in the paper, the researchers describe how the pre-service teachers evaluate the plastics island game and their motivation and self-efficacy toward implementing citizen inquiry. Rotman et al. (2014) motivation in citizen science or citizen inquiry is dynamic and changes over time. Hence, it is essential to know pre-service teachers' motivation toward implementing citizen inquiry for future teacher professional development suggestions. Besides, the researchers also measure pre-service teachers' self-efficacy to conduct citizen inquiry. In citizen inquiry, self-efficacy is the degree of pre- service teachers' confidence to participate in citizen inquiry (Phillips et al., 2017).

2. Literature Review

2.1 Understanding of Inquiry and Citizen Inquiry

To understand citizen inquiry, all need to know inquiry learning. Inquiry-based learning as a pedagogy was established a long time in line with the development of science. Many studies revealed that inquiry could enhance quality learning. There are several models in inquiry-based learning. In this paper, the type of inquiry differentiates by inquiry-type laboratories. According to Banchi and Bell (2008), there are four levels of scientific inquiry for learning: confirmation, structured, guided, and open. At the same time, Buck et al. (2008) stated that there are five levels of scientific inquiry: confirmation, structured inquiry, guided inquiry, open inquiry, and authentic inquiry. There are many versions of the steps of inquiry. However, a study by (Pedaste et al., 2015) stated that although there are differences between levels of inquiry. The main steps are still the same: Orientation, Conceptualization, Investigation, Conclusion, and Discussion.

Inquiry investigation with public participation is citizen inquiry. Citizen inquiry is citizen science's activity involving public participation led by scientific inquiry investigations (Herodotou et al., 2014). The public will contribute data to the scientist and apply it in their scientific research. (Herodotou et al., 2017). In addition, citizen inquiry allows people to work as a community and share their thoughts and knowledge on the topic people are interested in (Aristeidou et al., 2013).

According to (Adita et al., 2021), several technologies can support citizen inquiry. Citizen inquiry allows students to tackle the problem with an online-based platform. Hence, the learning activities become community-oriented (Aristeidou et al., 2013). Using technology in implementing citizen inquiry has several positive impacts, such as giving students authenticity (Ellenburg et al., 2019), experience, and raising students' awareness (Buchanan, Pressick-Kilborn, & Maher, 2018).

2.2 Learning Science through Digital Game

Learning through digital games can be one of the alternatives to provide students learning experience to cope with the problem related to the subject-specific content (Tapingkae, Panjaburee, Hwang, & Srisawasdi, 2020). As Prensky (2001a) mentioned, digital game-based learning combines serious learning,

engagement, interactive learning, and fun. According to (Qian & Clark, 2016), using the digital game in education has affected student learning significantly compared to non-game conditions.
Also, using a digital game can improve theoretical thinking skills significantly (Hussein et al., 2019)

According to (Srisawasdi & Panjaburee, 2019), game-transformed, inquiry-based learning can enhance conceptual understanding and motivation to learn chemistry. Open inquiry is acknowledged as a model to induce the student's progression toward scientific conceptual understanding (Srisawasdi & Kroothkeaw, 2014). Various game elements, including scoreboards, storylines, quests, contextualized feedback, and non-linear exploration of information used to support three core features of inquiry-based learning (Gao et al., 2019). While Chen, Huang & Liu (2019) suggested that the group that followed the predict-observe-explain (POE) inquiry scaffolds guide performed significantly better in both conceptual understanding and game performance.

Previous research (Adita et al., 2021) suggests that digital games can be applied in outclass activities. Meanwhile, the researchers can use hands-on experiment experiences in the in-class activity. The researchers proposed combining digital games with hands-on experiments in this design to give students new experiences. Then, digital games embedded with hands-on experiments potentially can achieve essential skills to be well-being students.

3. Methods

3.1 Sample Descriptions

A total of 21 pre-service science teachers participated in this study, consisting of 81% female and 19% male participants. The participants are majoring in general science in the second-and third-year grades. The researchers conducted two days of implementation in this implementation using the plastics island game.

3.2 Data Sources

3.2.1 Pre-service Teachers' Evaluation toward Plastics Island Game

The instrument was adapted from De Araujo Lima et al. (2022), and the instrument was translated into Indonesian by the researchers. This questionnaire consists of 12 items scored on a five-point Likert scale in which "5" represent "Strongly Agree," "4" represents "Agree," "3" represents "Neutral," "2" represents "Disagree," and "1" represents "Strongly Disagree." The test consists of twelve items with four dimensions: four items of interface components, four items of playability components, three multimedia components, and one item of games' story components. The instrument's internal consistency by Cronbach alpha is 0.872, indicating that the instrument has good reliability. In addition, in this study, the researchers also used an interview sheet with two questions on the game's evaluation. The interview took 15 minutes with four people as volunteers.

3.2.2 Pre-service Teachers' Motivation and Self-efficacy toward Implementation of Citizen Inquiry

The 5-point Likert scale questionnaire of motivation and self-efficacy toward implementing citizen inquiry was adapted from (Phillips et al., 2017). Then, translated into the Indonesian language by researchers. This questionnaire consists of 14 items scored on a five-point Likert scale in which "5" represent "Strongly agree," "4" represents "Agree," "3" represents "neutral," "2" represents "Disagree," and "1" represents "Strongly Disagree." The internal consistency of the motivation and self-efficacy questionnaire by Cronbach alpha is 0.781 and 0.836, respectively, implying that the instrument has good reliability.

3.2.3 Designing Digital Game based on Inquiry Practices

Previous research (Adita et al., 2021) shows that technology such as digital games can support citizen inquiry lessons. In this paper, the researchers highlight that the digital game in this research focuses on all the topics of microplastics compared to the previous analysis results (Adita et al., 2021). The digital game is only used on the issues impacting microplastics to the environment and human health (see table 1.1). This game has six missions embedded with the inquiry steps and hands-on experiment activity on four tasks. The actions of inquiry are stated clearly in the game interface: background information, asking questions, providing possible hypotheses, collecting the data/evidence, analyzing the data, and communicating the data. Figure 1 displays illustrative examples of the game on smartphones.

Figure 1. An illustration of the Plastic Island game: a video presentation of the problematic issue on plastic (left) and an inquiry-based investigative mission on the plastic waste situation (right)

For the implementation of the game, teachers have a pivotal role in guiding the students to complete the mission, especially in collecting evidence, analyzing data, and communicating the data. Based on the previous research by (Srisawasdi & Panjaburee, 2019), teachers' roles are in the pre-gaming and post-gaming phases, which consist of an open-ended question and introductory background whole post- gaming phase consists of results communication and conclusions. In this research, the teachers' role is to guide the experiment's steps, collect the data, and discuss the results and conclusions.

Table 1. *Descriptions of digital game content in the microplastics topics*

	Digital Game Content					
	Mission					
Topics of Microplastics	**1**	**2**	**3**	**4**	**5**	**6**
What is Microplastics	Hands-on Experiment (Observing Fish Fesses)	Hands-on Experiment (Cosmetics Products Filtration)				
How to Identify Microplastics			Hands-on Experiment (Simple Identification)			
How to Collect Microplastics				Hands-on Experiment (Collecting Microplastics with Ferrofluid)		

Impact of Microplastics to the Environment and Human Health		Video (River pollution in Indonesia)	Quiz (Drag and drop)
Competencies	**Microplastics Competencies**		

4. Results and Discussion

4.1 Pre-service Teachers' Evaluation toward Plastics Island Game

In this implementation, the researchers ask students to evaluate a plastics island game with four dimensions: interface, playability, multimedia, and story. Based on those criteria, the highest mean score was multimedia (Mean = 4.25, S.D. = 0.43), playability (Mean = 4.20, S.D. = 0.56), game's story (Mean = 4.10, S.D. = 0.77), and interface (Mean = 4.02, S.D. = 0.58), respectively. In addition, in this study, the researchers also interviewed four people as a volunteer in terms of game evaluation. Based on their argument, they were pretty satisfied with the game integrated with the inquiry steps, especially with the hands-on experiment embedded in the game design. However, there are drawbacks that researchers found during implementation, which are a slow internet connection and a short time of implementation. They argued that it needs a long time of training to operate the game, especially with the hands-on experiment. Figure 2 illustrates the results of pre-service teachers' evaluation regarding the four criteria.

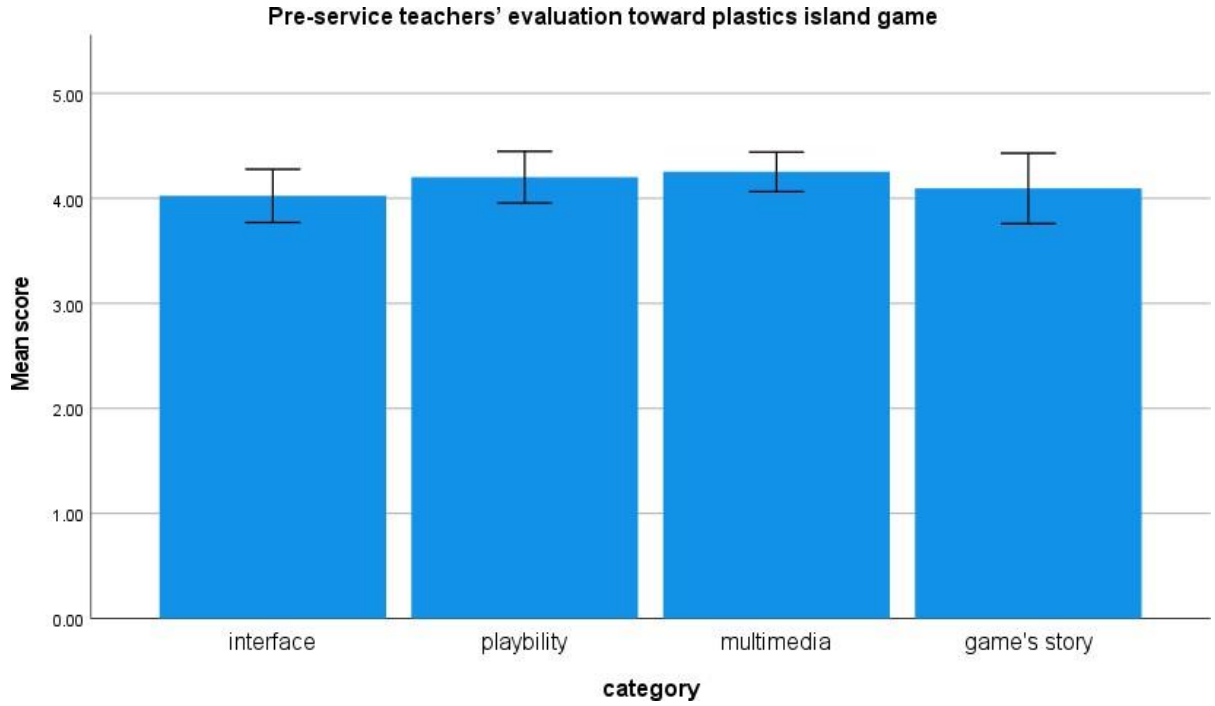

Figure 2. Pre-service teachers' evaluation of Plastics Island game

4.2 Pre-service Teachers' Motivation and Self-efficacy toward Implementation of Citizen Inquiry

This research also measures pre-service teachers' motivation toward implementing Citizen Inquiry. It is crucial to know the motivation of pre-service teachers toward Citizen Inquiry. Phillips et al. (2018) mentioned that motivation and self-efficacy are key potential outcomes of participating in citizen science. Table 2 categorizes motivation into two components: intrinsic and extrinsic motivation. In this research, pre-service science teachers' intrinsic motivation (Mean = 3.92, S.D. = 0.57) exceeds extrinsic motivation (Mean = 3.52, S.D. = 0.72). The data shows that pre-service teachers are more conscious of implementing citizen inquiry. In other words, pre-service teachers recognize that the activity is essential to achieve their goal instead of feeling fear or avoiding or having a negative feeling. Ryan and Deci (2000a; 2000b) also stated that a more intrinsically motivated person would have more effort and persistence for a particular activity. Motivation will drive students to engage more in citizen inquiry (Phillips et al., 2018).

Table 2. *Intrinsic and Extrinsic Motivation Scores in Implementation of Citizen Inquiry*

	Mean	Standard deviation
Intrinsic motivation	3.92	0.57
Extrinsic motivation	3.52	0.72

Phillips et al. (2018) also stated that motivation for citizen sciences is dynamic and complex. Therefore, motivation in the citizen inquiry is one of the variables that need to be measured to develop citizen inquiry in the future. Regarding self-efficacy, the pre-service teachers perceived their feeling about learning and understanding science content (Mean = 3.45, S.D. = 0.88) as equal to their feeling about doing citizen science activities (Mean = 3.51, S.D. = 0.96). Table 3 shows the results of pre- service teachers' self-efficacy in the pedagogy of citizen science or inquiry.

Table 3. *Pre-service Teachers' Self-Efficacy Scores regarding Citizen Science/Citizen Inquiry*

	Mean	Standard deviation
Pre-service teachers' feelings about learning and understanding science content	3.45	0.88
Pre-service teachers' feelings about doing citizen science activities	3.51	0.96

Another essential variable for citizen science is students' self-efficacy or a person's beliefs. In the context of citizen science, self-efficacy is very important in carrying out the principal activity (Crall et al., 2011). Also, self-efficacy indicates that students are confident about participating in the citizen project (Phillips et al., 2018). In this research, pre-service teachers' self-efficacy is categorized into two groups: pre-service teachers' feelings about learning and understanding science content and feelings about doing citizen science activities. Based on the table, there are slight differences between the two groups. However, both groups have a mean score surpassing three on a scale of 1 to 5. Overall, the pre- service teachers' self-efficacy is categorized well.

5. Conclusions

Research focuses on the pre-service science teachers' evaluation of the plastics island games and their motivation in implementing citizen inquiry. All in all, the results show that pre-service teachers' evaluation of the game is good. Their motivation to implement citizen inquiry mostly comes from intrinsic motivation. The mean intrinsic motivation score outnumbers the extrinsic motivation with 3.92 (S.D. = 0.57) and 3.52 (S.D. = 0.72), respectively, on a scale of 1 to 5. At the same time, pre-service teachers' self-efficacy shows good results, and the mean score surpasses three on a scale of 1 to 5. A digital game can be one of the alternative technologies to support citizen inquiry learning. A further suggestion is to implement the technology (digital game) for fostering pre-service teachers' skills in the teacher development program.

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