DEVELOPMENT ARTICLE

Investigating the design, participation and experience of teaching and learning facilitated by user-generated microgames on an open educational platform

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Abstract

Although user-generated microgames, defined as very simple games made by non-professionals on open platforms, are popular and appear to have considerable advantages in facilitating learning, further exploration is needed to establish their potential in instructional practices. The present study investigates the design, participation and experience of teaching and learning facilitated by user-generated microgames on an open educational platform. Through an exploratory experiment research method, four elementary school teachers designed and implemented microgame-based learning utilising these very small games on GeoGebra Classroom attended by 129 students. Data were gathered from lesson plans, classroom activity records and self-reflection questionnaires. This study revealed that teachers designed learning with various user-generated microgames and debriefing methods respecting learning content, but they shared comparatively similar scenarios by inserting microgame-based learning into the middle of the main session. The completion rate for the debriefing activity is minimum although the total joining times overshoot the number of students. Teachers found that user-generated microgames are acceptable to orchestrate short serious gaming sessions even though they are limited to one player with basic interfaces. Notwithstanding several disadvantages of these microgames recognised by students, such as missing learning instructions and inadequate interfaces, they so far enjoy learning by playing the games. The most critical implication of this study is to provide sufficient instructions and additional time for microgaming sessions in elementary schools to ensure sustainable completion of the briefing, playing and debriefing activities.

Introduction

Although user-generated microgames, defined as very simple games made by non-professionals on open platforms, are popular and appear to have considerable advantages in facilitating learning, further exploration is needed to establish their potential in current

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instructional practices. Their simplicity enables students to play without any prior knowledge about the games and as the microgames are short, encourage students to replay (Rahmadi et al., 2022). These simple, non-professional microgames have also been positively recognised by teachers as promising instructional media to stimulate motivational consequences in various learning scenarios (Rahmadi et al., 2023). The present findings emerged from purely exploratory studies which are mainly based on opinions instead of real classroom practices. Since there is an inconsistency between teachers' pedagogical beliefs and practices regarding technology integration in the classroom (Chen, 2008; Mertala, 2019; Thurm, 2018), it is critical to explore the integration of user-generated microgames into learning more experimentally.

While several studies have suggested trialling various purposeful games for learning; particular serious games, such as user-generated microgames, may contribute differently to teaching and learning. Therefore, understanding the usefulness of diverse games to facilitate instruction is important for providing more rigorous evidence (Brom et al., 2011; Connolly et al., 2012; Steinkuehler & Squire, 2023). Not only the games but various methodologies and contexts should also be taken into account to improve and continue the investigations (Yu et al., 2020). User-generated microgames are open educational resources and freely accessible learning materials for everyone (UNESCO, 2002). Experimenting with these microgames leads to a novel study line, which at the same time promotes inclusive access for students and teachers to a variety of digital learning resources (EDUCAUSE, 2020) to better perform in teaching and learning especially amidst and after the Coronavirus disease 2019 (Covid-19) outbreak.

Conceptual background

Applicable concepts regarding the use of user-generated microgames for learning are explained in this section. It covers (1) user-generated microgames; (2) microgame-based learning; (3) microgame-based learning scenarios. By referring to corresponding literature, each of them is described within one concise paragraph.

User-generated microgames appear as a relatively new term consisting of two terms: *user-generated content* and *microgames.* The concept of user-generated content allows Internet users to voluntarily create, modify, and share any content such as texts, sound, images, or videos on open platforms (Smith et al., 2012). Microgames in education were defined as very short games that provide brief engagement and meaningful experience for players, support learning and instruction toward specific objectives and integrate with existing resources (Rahmadi et al., 2021b). They are a subset of serious games fruitful to promote concise and meaningful learning exposures. In this exploratory experiment study, user-generated microgames were the focus.

Learning while playing games is simply called game-based learning (Richey, 2013), an innovative learning environment that utilises games as a means of gaining knowledge and skills (Qian & Clark, 2016). The process of learning from games is iterative, consisting of briefing, playing, and debriefing activities (Routledge, 2009). With further adjustment to the characteristics of microgames, the present study describes microgame-based learning as learning facilitated by very simple games which start with a briefing, then playing games as the main activity, and ends with a debriefing. Furthermore, considering the structure of microlearning that is very concise and brief (Hug, 2010; Lukosch et al., 2016), microgame-based learning may last around 15 min. The briefing activity therefore should

be short, followed by playing a microgame for around 5 min, and finished with a debriefing for the remaining time.

A learning scenario also called a learning path (Kurilovas et al., 2014), is a programmed but flexible structure of learning that commonly consists of beginning, middle and ending activities (Dimaraki et al., 2013). It could be a scenario for a single task or a whole course (Mezak & Papak, 2018). Scenarios for microgame-based learning are needed to bridge between theory and practice, encourage viable involvement, and accelerate knowledge and skills acquisition before, during and after game-based learning activities (Karadag, 2015; Smeureanu & Isăilă, 2017). This study considers basic scenarios of microgame-based learning (Rahmadi et al., 2023) which run within the main session of learning located between the opening and closing session. There are three basic possibilities to implement microgame-based learning namely at the beginning, in the middle, and at the end of the main learning session. Another more advanced possibility is to practise microgame-based learning by mixing two scenarios. Integrating microgames into all three scenarios can be considered regular game-based learning.

Literature review and study significance

This section reviews previous studies on the existing practice of microgame-based learning, the design of game-based learning, the student participation in game-based learning, the teacher and student experience with certain games, the game-based teaching and learning experiences, and the impact of game-based learning on elementary school students. The associated significance of the present study is also justified within each topic.

So far there has been little scientific evidence for the practice of game-based learning with very simple games created by users on open educational platforms. Existing studies tend to examine the effectiveness of microgames developed by professionals to support learning in school (Brom et al., 2011, 2015; Buchtová et al., 2013), university (Chai-Aray-alert & Puttinaovarat, 2021), workplace (Lukosch et al., 2016; Zhang & Qin, 2021), and public area (Bellotti et al., 2004) contexts. Their findings suggest that professional microgames are fruitful for students' learning individually or collectively, applicable to promote the cognitive growth of youngsters, a novel approach for employee training, and attractive to tourists. Investigating instructional practices facilitated by user-generated microgames could extend current findings and enrich the literature.

Studies on game-based learning design address mainly learning through games developed by researchers instead of teachers as one of the users. These studies have experimented with particular learning models (Chee, 2011; Foster & Shah, 2015), learning scenarios (Dickey, 2011; Lester et al., 2014), and game elements (Alaswad & Nadolny, 2015; Lan et al., 2018) to modify game-based learning environments. The findings generally show that those interventions influence students' learning experience and performance. The only intersecting research was conducted by Nadolny et al. (2017) who investigated how teachers select and implement game mechanics for their game-based learning in the classroom. Results from the study indicate that teachers change their selection and inclusion of game mechanics following students' needs. However, this was merely a survey study without detailed game design analysis and real classroom observation. A systematic literature review on game-based learning pedagogy has also shown that teachers implemented a variety of instructional activities at the briefing, playing, and debriefing stages of serious gaming in the classroom (Bado, 2019). Teachers may know learning objectives

better when designing a game-based scenario (Pivec & Pivec, 2010), thus their participation in the design process may contribute significantly to the game-based teaching and learning practices.

Research has shown that the participation of students in game-based learning is higher than in traditional teaching methods. Using games for teaching increases attraction and involvement (Lai et al., 2012; Liao et al., 2018). However, detailed studies on student participation in specific game-based learning activities either at the briefing, playing, or debriefing are sparse. Only the study of Gallegos et al. (2017) indicates low participation of students in online game-based learning because game tasks do not directly affect learning grades. In the other case, the study of Nadolny and Halabi (2016) reveals that students take part intensively in online serious gaming because they get points on each task for their final grades. Paying more attention to student involvement in specific game-based learning activities thus is important and the present study addresses this issue.

Different games provide differentiated experiences to teachers and students in teaching and learning. A plethora of commercial off-the-shelf games supports learning. The games could provide a fun and meaningful experience at the same time for students (Aleksić et al., 2016), but teachers have to carefully select them (Becker, 2017) and schools need to provide strong financial resources (Ritzhaupt et al., 2010). Another option is to take advantage of either long-duration or short-duration purposive games. The short ones, which are usually called microgames, seem more suitable for formal educational environments (Brom et al., 2011) because teachers may easily insert them into their teaching and students do not need a long time to play. These microgames can be generated professionally or created voluntarily by users of open platforms. This study examines microgames developed by GeoGebra's users, further exploring their affordances in teaching and learning practices.

When teaching and learning take place while playing games, teachers and students perceive various positive and negative impressions. Teachers perceive that game-based learning is a powerful teaching method to motivate students and provide them with an authentic learning environment (Huizenga et al., 2017; Rahmadi et al., 2021a), but it is challenging in its implementation due to pedagogical and technological constraints. They experienced problems with time planning and non-cooperative behaviours of students (Ucus, 2015), difficulties in adjusting their roles when teaching by games and dealing with a rigid school curriculum (Allsop & Jessel, 2015). There is a lack of technical support such as limited games that match learning objectives (Watson & Yang, 2016), and adequate technologies in schools (Rice, 2007). Similarly to teachers, students also accounted for serious gaming as a comparatively interesting instructional technique (Mathrani et al., 2016), giving them more satisfaction in learning (Davidson & Candy, 2016). The present study extends the current understanding of not only positive but also negative impressions of teaching and learning enhanced by games.

Game-based learning by far has a significant impact on the motivation and learning outcomes of elementary school students. Available research found this effect, especially on mathematics and science subjects as well as on STEM education. The study of White and McCoy (2019) and Hung et al. (2014) reveal that learning by playing purposeful games considerably escalates learners' attitude, motivation, self-efficacy and academic achievement in elementary mathematics classes. In particular, by utilising a number navigation game, Brezovszky et al. (2019) indicate its contribution to enhancing elementary school students' comprehension of adaptive numbers. A systematic review of the digital game-based learning effects on elementary science learning has revealed that this way of learning is promising especially for knowledge acquisition and motivational and skills development (Hussein et al., 2019). Wang et al. (2022) further disclose that serious gaming also

contributes to the betterment of students' learning achievement in science, technology, engineering and mathematics (STEM) education. According to Mayer (2014), motivational and cognitive consequences are prevalent effects of game-based educational environments that should be taken seriously into consideration in future practices.

Various topics were examined in this literature review to promote a comprehensive understanding of what has been done so far and to elevate the discussion in a later section. As this article addresses these matters: design, participation and experience of microgame-based learning, relevant previous studies were reviewed. It reveals that studies about serious gaming were mostly based on researchers' designs instead of teachers' ones. The practice by far merely involved professional-made microgames instead of user-generated microgames. Following the design and practice, it could be meaningful to evaluate exposures. Therefore, it also reviews student engagements as well as student and teacher experiences in game-based learning to compare with the case of microgame-based learning. Finally, the impacts on elementary school students were described because this study involved similar participants.

Purpose and research questions

The present study investigates the design, participation and experience of teaching and learning facilitated by user-generated microgames on an open educational platform. The following questions were considered in this study:

1. How do teachers design microgame-based learning for their teaching practices utilising user-generated microgames on an open educational platform?
2. How was students' participation in microgame-based learning with user-generated microgames on an open educational platform?
3. What negative and positive experiences are perceived by teachers and students in microgame-based teaching and learning facilitated by user-generated microgames on an open educational platform?

Findings from this study contribute to the growing body of knowledge on microgame-based learning with serious games made by open platform users. Detailed methodology and methods used in the study are presented in the next section. Finally, this article turns to its main sections covering results, discussion, and conclusions including current evidence, a critical review of findings and reflections on studies that might follow.

Methods

An exploratory experiment research method was used in this study. The method allows experimental studies to be more flexible without any hypotheses and has a more comprehensive and systematic role in scientific investigations (Franklin, 2005). This method is also called innovative exploration (Stebbins, 2001) as a means of gaining familiarity with studied problems or procedures by several interventions to achieve a desired effect or product. Rather than testing hypotheses, the exploratory experiment method employs a variety of systematised strategies and utilises background knowledge to establish novel correlations, follow anomalies, or seek improvements (Burian, 2013). In other words, this

study lies on the exploratory nature of research instead of the confirmatory ones (Johnson & Christensen, 2019) to generate ideas and construct relevant concepts or theories in the early phases of research about the practice of microgame-based teaching and learning with user-generated microgames on an open learning platform.

Participants

The present study was participated in by four teachers and 129 students at elementary schools in Indonesia. These teachers were purposefully selected concerning grade levels and school locations in which they are teaching. Detailed information about their profiles is presented in Table 1.

Table 1 describes the profile of elementary school teachers who participated in the study. Gender balance is provided. Two of them are aged 26 and 29 years old while the rest are over 40 years old with bachelor's and master's educational backgrounds. Only one teacher has experience in teaching for less than five years and two teachers already have experience in game-based learning (GBL). They teach in public elementary schools at high-grade levels from grades IV to VI in different areas of Indonesia. It is fundamental to note that before the study, teachers received a short introduction from researchers to the utilisation of user-generated microgames for supporting learning. The intro was aimed at familiarising them with these relatively new teaching media, but not at influencing their preferences for integrating microgames into their teaching practices. Nevertheless, it is crucial to acknowledge that this introductory activity might affect their choices as well.

Table 2 describes the profile of students who participated in the study. There are 129 students in total with an almost equal gender proportion between males and females. Almost 70% of students are aged between nine and ten years old, and nearly 28% of students are aged from eleven to twelve. They reside proportionally in different areas of Indonesia. Over half of them are in grade IV while there is nearly a shared proportion for students in grades V and VI accounting for 24.81 and 24.03% respectively. There are around 35% of students already experienced in learning with games. Smartphones by far are their most popular learning devices. Before practising microgame-based learning, students received a brief explanation from teachers about the activities which include briefing, playing and debriefing. It was the first time for them to join game-based learning facilitated by user-generated microgames on an open educational platform.

Regarding the categorisation of participants' residences, the term *village* refers to a location in a rural area which is smaller than a town. In this study, the village was Arosbaya, Bangkalan. The term *town* reflects a place in a suburban area which is larger than a village but smaller than a city. In this study, the town was Pangkalpinang, Bangka Belitung. The term *city* relates to a site in an urban area which is larger than a town but smaller

Table 1 Profile of teachers participating in the study

Teacher	Gender	Age	Education	Experience	GBL Exp.	School	Grade	Location
T1	Female	48 years	Master	15 years	Never	Public	VI	Village
T2	Male	41 years	Master	12 years	Ever	Public	IV	Town
T3	Male	26 years	Bachelor	3 years	Ever	Public	IV	City
T4	Female	29 years	Bachelor	7 years	Never	Public	V	Megacity

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Table 2 Profile of students participating in the study

Gender			
Male	Female		
59 (45.74%)	70 (54.26%)		
Age			
<9 years	9–10 years	11–12 years	>12 years
2 (1.55%)	89 (68.99%)	35 (27.13%)	3 (2.33%)
Location			
Village	Town	City	Megacity
31 (24.03%)	33 (25.58%)	33 (25.58%)	32 (24.81%)
High-grade level			
IV	V	VI	
66 (51.16%)	32 (24.81%)	31 (24.03%)	
Game-based learning experience			
Never	Ever		
85 (65.89%)	44 (34.11%)		
Learning devices			
Desktop computer	Laptop	Smartphone	
2 (1.55%)	7 (5.43%)	120 (93.02%)	

than a megacity. In this study, the city was Depok, Jawa Barat. The term *megacity* indicates a position in a highly populated urban area which is larger than a city. In this study, the megacity was Jakarta Timur, Daerah Khusus Ibu Kota Jakarta.

Procedures

This exploratory experiment was divided into three stages namely design, implementation and reflection. These steps were taken to systematically run the study despite its exploratory nature. The figure below illustrates the processes in detail.

Figure 1 describes the process of the study. The exploratory experiment started with the design phase, teachers selected one user-generated microgame from GeoGebra suitable for their teaching and created a lesson plan (see Appendix 1). Based on their plans, they developed microgame-based learning on GeoGebra Classroom, a virtual classroom for science, technology, engineering, and mathematics (STEM) learning with real-time progress

Stages	**Design**	➡	**Implementation**	➡	**Reflection**
Activities	• Selecting a user-generated microgame from GeoGebra • Designing a lesson plan • Developing microgame-based learning on GeoGebra Classroom		• Implementing microgame-based learning on GeoGebra Classroom		• Reflecting on microgame-based learning experience
Actors	Teacher Researcher		Teacher Student		Teacher Student
Data	Lesson plan		Classroom activity record		Self-reflection feedback
Analysis	Descriptive		Descriptive		Descriptive

Fig. 1 Exploratory experiment processes

reports (Zöchbauer & Hohenwarter, 2020). The classroom is one of the applications on GeoGebra, an interactive geometry, algebra, statistics and calculus application for teaching and learning at the school and university level (*About GeoGebra*, 2021). The researcher, the first author of this article who is a lecturer at a private university in Indonesia with 5 years of teaching and research experience, supported any technical issues in the development of teachers' GeoGebra Classrooms. He has a background in educational technology and has been exploring user-generated microgames on open educational platforms for three years. Screenshots of the developed classrooms are available in Appendix 2. The process was continued by implementing microgame-based learning conducted by teachers and participated in by their students. Students joined teachers' classrooms simply by a unique link. It was not necessary for students to register and log in to the GeoGebra application. This practice was implemented within regular synchronous online learning amidst the Covid-19 pandemic. Teachers inserted their microgaming activities into a particular part of the main learning session. The final stage is a reflection on their experiences.

Data collection and analysis

Teachers' lesson plans, activity records in the GeoGebra Classroom and self-reflection feedback through online questionnaires were the data sources and collection tools in this study. The lesson plans were developed by the teachers themselves with a template from the researcher. Their activities were automatically recorded on the GeoGebra system enabling further analysis with ease. Teachers and students filled out open-ended self-reflection questionnaires on Google Forms. It was a short questionnaire and was intentionally made as simple as possible to respect the participants who were elementary school students. Besides their backgrounds, the main questions asked in the questionnaires were about negative and positive experiences with microgame-based learning facilitated by user-generated microgames as well as recommendations to improve their experiences.

Respecting the research questions posed in this study, the generated data from each technique were featured as follows.

- Collected data from the lesson plans were used to answer the first question: How do teachers design microgame-based learning for their teaching practices utilising user-generated microgames on an open educational platform? The evaluation of their design was based on the conceptual foundation regarding the basic scenarios of microgame-based learning.
- Recorded activities on the teachers' GeoGebra Classroom were used to answer the second question: How was students' participation in microgame-based learning with user-generated microgames on an open educational platform? The observation of their participation was based on the conceptual basis of microgame-based learning paces focusing on the joining times and the completion of playing and debriefing activities.
- Received data from the questionnaires were used to answer the third question: What negative and positive experiences are perceived by teachers and students in microgame-based teaching and learning facilitated by user-generated microgames on an open educational platform? The exposures were categorised based on the positive and negative ones complemented by their recommendations.

Data collection tools used in this study were inspected by other researchers who are also co-authors in this article to ensure that every single element and question is accurate

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and reliable (Kimberlin & Winterstein, 2008). All collected data were analysed descriptively by a descriptive statistics technique to simplify, analyse and describe the key features of the data (Holcomb, 2016), starting by tabulating data, adding percentage scores on the data, and presenting the analysed data in concise tables. Additionally, open coding (Glaser, 2016) was employed to code and summarise results from the open questionnaires. The students' and teachers' poor and good exposures were carefully identified from negative and positive words in their responses. In many cases, they separately expressed both impressions including their recommendations per line so that was easy to distinguish.

Ethics

The teachers and students voluntarily participated in this study and issues about research ethics have been communicated in advance to them. First, teachers were informed that their involvements are anonymous, no one could identify their names or their school names. Further, the researcher has agreed with teachers that the participation of students in this study would not influence any formative and summative examination grades. Teachers have also communicated this matter with students before the microgame-based teaching practice starts. The teaching and learning activities and all generated data from the study thus were used exclusively for scientific purposes.

Results

The next sections present gathered data from this study. To answer the asked research questions, these results are distributed into three corresponding passages, namely: (1) microgame-based learning design; (2) participation in microgame-based learning; and (3) microgame-based teaching and learning experiences. The data are visualised in corresponding tables followed by careful descriptions.

Microgame-based learning design

Microgame-based learning designs were examined descriptively, based on lesson plans made by teachers. The examination covers their topics, activities in microgame-based learning and preferred scenarios. Within the microgame-based learning activities, briefing methods, played microgames and strategies for debriefing were inspected. Table 3 summarises information gathered from the examination of the learning designs.

Table 3 describes the design of microgame-based learning developed by teachers. The teachers utilised various user-generated microgames and debriefing approaches to address different topics while they administered fairly similar scenarios. Those topics include addition and subtraction, fractions, solid geometry, and line charts. All teachers started microgame-based learning with introductory texts. Briefing with texts appears as the easiest way to introduce defined learning objectives and activities. Different games from GeoGebra were utilised by teachers which were selected respecting their suitability to deliver the intended mathematical topics. Two teachers were using open-ended questions for debriefing whilst the two others asked students simple multiple-choice and case-study multiple-choice questions. The variety of debriefing activities indicates that teachers also consider content characteristics in designing microgame-based learning. Three out of four teachers inserted the microgame-based learning in the middle of the main learning session thus
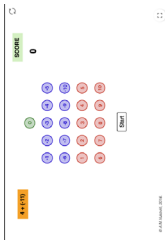
Table 3 Design of microgame-based learning

Teacher (T)	Topic	Microgame-based learning			Scenario
		Briefing	Playing	Debriefing	
T1	Addition and subtraction	Introductory text	www.geogebra.org/m/eNyT6MUp	Case-study multiple choices	Ending
T2	Fractions	Introductory text	www.geogebra.org/m/m2RrAWsc	Open-ended	Middle
T3	Solid geometry	Introductory text	www.geogebra.org/m/UNZKjguG	Multiple choices	Middle
T4	Line chart	Introductory text	www.geogebra.org/m/rPz62pz9	Open-ended	Middle

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Table 4 Recapitulation of joining times in microgame-based learning

Teacher (T)	Location	GeoGebra classroom (GC)	Number of students	Join times
T1	Village	www.geogebra.org/classroom/pndtkscp	31	76
T2	Town	www.geogebra.org/classroom/zsu7ytsc	33	85
T3	City	www.geogebra.org/classroom/sfbm6kdm	33	72
T4	Megacity	www.geogebra.org/classroom/xdgqh2eg	32	215
Total			129	448

Table 5 Recapitulation of playing activity completions

Teacher's GeoGebra classroom (TGC)	Location	Not started	Uncompleted	Completed	Join times
TGC1	Village	36 47.37%	15 19.74%	25 32.89%	76 100%
TGC2	Town	42 49.41%	17 20.00%	26 30.59%	85 100%
TGC3	City	12 16.67%	15 20.83%	45 62.50%	72 100%
TGC4	Megacity	58 26.98%	114 53.02%	43 20.00%	215 100%
Total		148 33.04%	161 35.94%	139 31.03%	448 100%

only one of them used it at the end and no one integrated it at the beginning or mixed the scenarios.

Participation in microgame-based learning

Students' participation was automatically recorded in the platform so that was possible to analyse joining times and activities in each classroom. This microgame-based learning was openly conducted over the GeoGebra Classroom. Students join in the classroom using a code shared by their teachers. They were not required to have an account and sign in to the platform. Table 4 recaps the joining times as well as playing and debriefing activities.

Table 4 summarises the number of joining times in microgame-based learning in each teacher's GeoGebra Classroom. Overall, there are many joining times exceeding the number of students in all classrooms and this is highly noticeable for those in the megacity. Joining times on the teacher's GeoGebra Classroom from the megacity reached 215 times which is three times as many as those from other regions. The total joining times are also triple the number of students reaching 448 times while there are only 129 students.

Table 5 summarises the completion of playing activities in each teacher's GeoGebra Classroom based on the joining times. There is a surprisingly highest completion on the teacher's GeoGebra Classroom from the city instead of those from megacity. Meanwhile, there is a nearly shared percentage between not started, uncompleted and completed playing activities in total over the different regions. Completed playing activities on the teacher's GeoGebra Classroom from the city reached over 60% of the join times while there

were only 20% playing completion on the teacher's GeoGebra Classroom from the megacity. It is also notable that almost 50% of the join times on the teachers' GeoGebra Classroom from village and town have not even started the playing activity. For the total, it is relatively equal that there are over 30% of not started, uncompleted and completed playing activities.

Table 6 summarises the completion of debriefing activities on each teacher's GeoGebra Classroom based on the joining times. There is a surprisingly highest debriefing completion on the teacher's GeoGebra Classroom from the city instead of those from the megacity. Meanwhile, in total, the percentage of not started debriefing activity is remarkable. Completed debriefing activities on the teacher's GeoGebra Classroom from the city reached 75% of the join times while there was less than 20% debriefing completion on the teacher's GeoGebra Classroom from the megacity. It is also noticeable that over 90% and 60% of join times on the teachers' GeoGebra Classroom from village and town have not even started the debriefing activity. In total, no more than 30% of total join times completed the debriefing.

Microgame-based teaching and learning experiences

Open questions on online questionnaires asked teachers and students to reflect on their experiences during the design and implementation of microgame-based learning with user-generated microgames on GeoGebra Classroom. The open-ended questionnaires deal with teachers' and students' positive and negative exposures as well as recommendations for improving microgame-based teaching and learning. Detailed information about their experiences is presented in Table 7.

Table 7 describes the positive and negative experiences of teachers (T) and their recommendations for improving microgame-based teaching. Overall, teachers have relatively shared positive and negative impressions. They are positively impressed by the easy-to-use, effective and useful aspects but less so by the plain user interfaces, one-player and limited duration characteristics. Teachers recommend more interesting and relevant interfaces, multi-player and multi-level capability and careful planning to ensure step-by-step microgame-based learning.

Several illustrative quotations of teachers' positive exposures are available below.

Table 6 Recapitulation of debriefing activity completions

Teacher's GeoGebra classroom (TGC)	Location	Not started	Uncompleted	Completed	Join times
TGC1	Village	71 93.42%	0 0.00%	5 6.58%	76 100%
TGC2	Town	55 64.71%	6 7.06%	24 28.24%	85 100%
TGC3	City	18 25.00%	0 0.00%	54 75.00%	72 100%
TGC4	Megacity	173 80.47%	0 0.00%	42 19.53%	215 100%
Total		317 70.76%	6 1.34%	125 27.90%	448 100%

Table 7 Teachers' experience of microgame-based teaching

Positive (P)	Negative (N)	Recommendations (R)
P1. Easy-to-use—no prior knowledge about the game features, use it easily	N1. Plain—game interfaces without animations and sounds	R1. Interfaces—more interesting interfaces that fit students' characteristics
P2. Effective—deliver and evaluate learning in a short time	N2. One-player—available only for single player	R2. Multiplayer—possibilities to play together with peers
P3. Useful—for reinforcing and meaningful learning	N3. Limited—levels to play and short playing duration	R3. Multilevel—various levels with different playing time
		R4. Careful planning—ensuring the step-by-step of microgame-based teaching

T1 It was quite satisfying to teach using microgames because it helps to reinforce students' understanding of learning material and could be a means for evaluating learning at the same time. (P2, P3)

T3 Teaching with microgames was my first experience, these games are very easy to use because there is no need to learn the features. (P1)

Some illustrative quotations of teachers' negative exposures are as follows.

T2 The game's appearance is too simple without sound and animated effects that can be more attractive to students. (N1)

T4 It was not possible for students to play together in one game, students only played their games for a relatively short time. (N2, N3)

Multiple illustrative quotations of teachers' recommendations are provided below.

T1 To start with elementary school students, I think these microgames should have simple content or tasks and enough time to play. For smarter students, the difficulty level can be increased. (R3)

T3 It is important to manage the sequences before and after playing the games to ensure that students have a consistent interest in learning. (R4)

Table 8 describes the positive and negative experiences of students (S) and their recommendations for improving microgame-based learning. Overall, students felt that microgames-based learning with user-generated microgames is interesting, challenging, fun and useful. However, some microgames had unclear instructions, were somehow complicated, hard to understand and of limited duration. They also experienced limited internet access. Their recommendations were to improve the instructions, interfaces, local language and duration of the microgame-based learning.

Various illustrative quotations of students' positive exposures are described below.

S7 Very challenging and tests the speed of thinking and the accuracy of choosing answers. (P2)

S62 In my opinion, it was very delightful because we could play while learning and the learning material was easier to understand. (P1, P3, P4)

S82 Creating an enjoyable environment increases enthusiasm and motivation for learning. (P1)

Some illustrative quotations of students' negative exposures are as follows.

S43 The game appears very small; it was difficult for me to play on my hand-phone. (N2)

S56 I am constrained because the language used in the game is English. (N3)

S113 Limited by internet quota, lack of explanation from the teacher, time was too short. (N1, N4)

Several illustrative quotations of students' recommendations are noted below.

S18 Teachers should be clearer in showing how to play the game. (R1)

S39 Please provide more games made in Bahasa Indonesia. (R3)

S92 The game can be equipped with a short explanation of learning materials, making it easier to play and remember the corresponding content. (R1)

Table 8 Students' experience of microgame-based learning

Positive (P)	Negative (N)	Recommendations (R)
P1. Interesting—learning with playing games	N1. Unclear—the instructions and questions	R1. Instruction—clearly showing how to play games and what is the relevant learning materials
P2. Challenging—train thinking speed and accuracy	N2. Complicated—small numbers and pictures, especially when playing on smartphones	R2. Interfaces—bigger numbers and pictures with various colours and animations
P3. Fun—learning can be more fun with games	N3. Hard—the games are in English	R3. Language—games in Bahasa Indonesia
P4. Useful—easier to understand learning materials	N4. Limited—short playing duration, internet access	R4. Time—a longer time to play games

Provided examples of teachers' and students' statements highlight the current findings more narratively and it is expected to be useful in endorsing a more comprehensive understanding.

Discussion

The present study was aimed at investigating the design, participation and experience of teaching and learning facilitated by user-generated microgames on an open educational platform through a more experimental but still explorative treatment. This study was constructed from the already-known concepts of user-generated microgames, microgame-based learning and microgame-based learning scenarios. The current findings are compared with relevant literature on the existing practice of microgame-based learning and other related concerns. Evidence from this study provides prospective interventions and state-of-the-art rationales for microgame-based learning facilitated by user-generated microgames. Besides this discussion, implications for practice and theory as well as limitations and avenues for upcoming research are addressed.

Teachers employ diverse user-generated microgames and debriefing methods to address definite topics. It is in line with the study of Nadolny et al. (2017) revealing that teachers alter game mechanics to conform to student and instructional needs. This is also consistent with the review of Bado (2019) stating that teachers vary learning activities in the pre-game, game and post-game phases. The present study further discloses novel evidence respecting their implemented scenarios which unfortunately remain monotonous. Teachers tend to integrate these microgames into the middle of main learning sessions, and this fact confirms what Rahmadi et al. (2023) found in their investigation toward teachers' preferences for integrating microgame-based learning in various scenarios. They argue that incorporating microgames in the middle of the core classroom part is suitable for reinforcement while enabling them to explain learning materials at the beginning and evaluate student understanding at the end. Any interventions against game-based learning such as with particular learning scenarios (Lester et al., 2014), learning models (Foster & Shah, 2015; Saimon et al., 2023) and game elements (Lan et al., 2018) may influence learning experience and achievement. Therefore, it becomes essential to introduce teachers to innovative routes for teaching with educational microgames, beneficial for not only guaranteeing students' but also teachers' impressions and performances.

From the instructional design perspective, as this study invited teachers to configure and execute microgame-based learning, it supports the notion of pedagogical co-design activities. Several advantages can be identified. Firstly, teachers were able to enact their technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2005) in the specific context of serious games. Through the design, development and implementation activities, they can simultaneously rehearse and enhance their understanding of educational games and their contribution to support learning. Their knowledge matters since for successful game-based teaching and learning practices, they need to be familiar with the content and the technology being used as well as have a solid understanding of how to utilise games in the educational context (Tay et al., 2022). Secondly, teachers' involvements contribute to the superior curriculum alignment. Teachers are more aware of the learning objectives and the subject matters than researchers or developers (Pivec & Pivec, 2010). Designing game-based learning in collaboration with teachers ensures that every single stage aligns with the curriculum and that students are mastering the necessary content or skills. Finally, this

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way of collaboration bridges the newest research and pedagogical innovations into praxis (Law et al., 2014; Aksela, 2019). Teachers were collaborating with researchers to co-create game-based learning activities in their classrooms. It ascertains that the conducted micro-game-based learning activities are grounded in the latest research and are well-suited to the needs and abilities of elementary school students.

The disciplinary nature of mathematical topics may influence the microgame-based learning design in multiple aspects. Selected user-generated microgames are surprisingly simple, created by regular people as users of GeoGebra. In this study, they appear acceptable to teach elementary mathematics on the topics of addition and subtraction, fractions, solid geometry and line charts, whilst may not be suitable for teaching higher mathematical concepts. Reflecting on other subject matters such as biology or history will need more personalised mechanics (Arnab et al., 2015) and other game elements like aesthetics, story, technology and pedagogy. Microgames that were designed to teach mathematics may involve solving math problems by direct instruction while for teaching biology or history, the games could entangle making decisions based on scientific facts or historical events through inquiry-based learning. These subject matter characteristics stipulate the less generalisability of investigations (Hultsch et al., 2002) on learning by playing in an individual discipline.

It is also interesting to discuss the possible influence of using user-generated microgames on overall teaching and learning practices. The leading effect might be on the learning trajectory, respecting microgame-based learning scenarios, there are three different micro sessions: beginning, middle and end. Each session reflects the nature of microlearning that should be concise and more importantly be integrated into the meso and macro learning structures (Hug, 2010). Teachers may need to allocate teaching time respectively over these smaller lessons and break learning materials down into shorter forms. At one of these schemes, depending on which one they choose, teachers should ensure the implementation of microgame-based learning that consists of briefing, playing and debriefing activities. Further, they are suggested to connect user-generated microgames creatively not only to understand learning content but also to master skills and literacies, as open platform users created their educational microgames with anything that is not always directly related to learning materials (Rahmadi et al., 2022). This relatively different instructional approach invites students to learn promptly and focuses on specific knowledge and skills. They learn from tiny pieces of content presented in user-generated microgames.

In the implementation of microgame-based learning, the total joining times overshoot the number of students while there is a relatively minimum completion rate for the debriefing activity. Students, especially those from the megacity, joined GeoGebra Classroom several times. Using games for learning attracts student participation (Liao et al., 2018). Meanwhile, their multiple attempts to take part in the microgaming session on the GeoGebra platform denote that they face difficulties. These may comprise either technical or pedagogical handicaps from the side of students, teachers, or the system which need a deeper investigation. Students were not registered to GeoGebra so if they rejoin the classroom it is counted as a new record. Further, they seem to be less challenged or otherwise discover many troubles when coming to the debriefing activity. Predictably, this low completion is due to the voluntary task without a direct correlation to final grades (Gallegos et al., 2017). Should the discussion be mandatory and contribute to learning scores, they presumably would participate (Nadolny & Halabi, 2016). This finding denotes that is crucial to ensure complete participation during the microgame-based learning processes.

The experience of teachers in microgame-based teaching with user-generated microgames so far is balanced between the negative and positive ones. On the one hand, the

characteristic of user-generated microgames suits short serious gaming sessions. They are accessible and playable in a short period to assist authentic teaching (Huizenga et al., 2017; Rahmadi et al., 2022). Unlike regular game-based learning (Allsop & Jessel, 2015; Watson & Yang, 2016), teachers did not express any difficulties in finding microgames, using adequate technologies, and dealing with the rigid school curriculum. On the other hand, the microgaming session is mostly linear to one player with basic interfaces. These microgames were produced by non-professional people on open platforms so their mechanics and aesthetics are somehow confined. Unexpectedly, the short play on microgame-based teaching at the same time is recognised by teachers as another drawback. This may be the case by virtue of the microgame-based teaching practices in elementary schools with young children. It is normal that teachers have to switch their roles and apply different classroom arrangements when teaching by games (Ketelhut & Schifter, 2011; Ucus, 2015). To mitigate these disadvantages, users may pay more attention to interfaces when creating microgames and teachers are suggested to carefully plan microgame-based learning.

The experience of students in microgame-based learning appears to be also balanced. Notwithstanding several disadvantages, they so far enjoy learning while playing user-generated microgames. Their enjoyment substantiates the remark of Yien et al. (2011) and Mathrani et al. (2016) who conclude that serious gaming is a pleasing learning model. On the other hand, they are negative about the lack of learning instructions and basic user interfaces, games in English rather than their language, and the limited time to play and internet access. The first three disadvantages confirm the opinion of teachers in the investigative exploration of Rahmadi et al. (2021a), they argue that using user-generated microgames to assist learning may be problematic for students due to minimum instructional guides, lack of interfaces, and non-native language in the games. Students' responses about insufficient time to play correspond with the teachers' experience in this study, emphasising that not only teachers but also students are in need of longer time to practise microgame-based teaching and learning in elementary schools. Access to the Internet connection is a prevalent problem in developing countries (Tadesse & Muluye, 2020). Students recommend establishing proper learning instructions, simpler microgames in their language with adequate interfaces and longer playtime in microgame-based learning. These empirical findings form a basis for future studies.

Implications for practice and theory

The findings of this study have a number of implications for the future practice of microgame-based teaching and learning with user-generated microgames. First of all, teachers need to select available user-generated microgames according to learning objectives and contents. This initial step is fundamental to ensuring the performance and satisfaction of either students or teachers in the microgaming practices. Further, it is suggested that teachers explore microgame-based learning in different scenarios. Having careful planning is another key success for the implementation of microgame-based learning. This includes providing sufficient instructions and times so that the learning could run steadily with acceptable completion of the briefing, playing, and debriefing activities. In particular, the debriefing should have a direct relation to learning grades, thus students are more likely to finish. Simpler games created with proper interfaces in the student's native language are needed by elementary school students to better perform in learning through non-professional microgames. Finally, the application of microgame-based learning on an open

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platform requires registered users so that they can continue learning automatically and do not count as a new joining attempt.

The present study enhances the conceptual understanding of user-generated microgames, microgame-based learning, and microgame-based learning scenarios. In online learning environments, these microgames may be defined as digital games generated by users of open educational platforms. The procedures of microgame-based learning could be agreed which consist of the briefing, playing, and debriefing actions. Meanwhile, the duration should remain flexible depending on the corresponding context, as practising microgame-based learning in elementary schools takes longer times. It is faintly to state that the serious microgaming should last only around 15 min although keeping it as concise as possible is recommended. The concept of microgame-based learning scenarios (Rahmadi et al., 2023) is relevant to the practice of teaching and learning through very simple and short games in the actual classroom. It helps teachers to place microgame-based learning somewhere in the main learning session either at the beginning, middle, ending or mixed for more advanced schemes.

Limitations and future research

Several caveats have to be made regarding the current research. This study focused on investigating the design and implementation of online microgame-based learning facilitated by user-generated microgames with the participation of elementary school teachers and students from a single country in an exploratory way. Involved teachers and students have early exposure to utilising these games for learning. The study findings serve as preliminary evidence and knowledge of actual microgame-based learning practices. The effectiveness of particular user-generated microgames and microgame-based learning scenarios especially concerning participants' backgrounds as well as these games' influence on entire instructional strategies could not be concluded empirically from the present investigation. These limits pinpoint upcoming experimentations. It is worth further confirming which kind of user-generated microgames or which microgaming scenarios are more effective in facilitating learning and how they influence instructional practices through true- or quasi-experimental studies and design-based research. From the angle of students' and teachers' profiles, it is interesting to examine whether certain age, gender or residence influences their preferences for playing and learning through these very simple games. A comparison with non-game-based lessons would be needed as performance measures. This study was limited to elementary schools and expanding the exploration with secondary school teachers and students may yield heterogeneous evidence and enrich understanding of microgame-based learning practices at multiple school levels.

Conclusions

The present study has investigated the practice of microgame-based learning utilising very simple non-professional educational games conducted by elementary school teachers on an open platform. It was focused on the design and participation in microgame-based learning as well as the teaching and learning experiences. This study revealed that teachers applied microgame-based learning in different ways yet they share similar scenarios. High joining times in microgame-based learning do not guarantee a completion rate of debriefing activity. User-generated microgames are suitable for short serious gaming sessions despite

being limited to one player with basic interfaces. Learning while playing these microgames is enjoyable notwithstanding several disadvantages such as missing learning guides and inadequate game interfaces. One most critical implication of this study is to provide sufficient instructions and times for microgaming sessions in elementary schools, ensuring sustainable completion of the briefing, playing, and debriefing activities. The current evidence establishes fundamental knowledge of the practice of microgame-based learning with user-generated microgames for future endeavours.

Declarations

Conflict of interest The authors declare that there is no conflict of interest in this study.

Ethical approval Concerns about research ethics have been communicated in advance to teachers and students. Their involvements are anonymous and all gathered data is used only for scientific purposes.

Research involving human and animal participants All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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