INTEGRATING DIGITAL GAMES IN THE CLASSROOM: A CASE STUDY WITH GAME PROBCHALLENGE

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This paper reports how a mathematics teacher uses a digital game for learning and teaching in the classroom. We utilize a case study approach to examine the pedagogical activities present in the lesson. The results of the study indicate that not all of the lesson objectives were met. Even though the teacher planned the lesson and the activities for the students, his lack of knowledge about game-based pedagogy had an impact on the learning outcomes.

Keywords: digital game, DGBL, mathematics teacher, pedagogical activities

INTRODUCTION

Digital games are played in digital settings that permit interaction with electronic systems that provide visual feedback (Moore-Russo et al., 2015). Digital game-based learning (DGBL) refers to any educational activity that incorporates digital games. Research on the use of digital games has demonstrated positive outcomes not only for K-12 students but also for college students in terms of motivating them to learn mathematics, increasing their engagement, fostering active participation, and enhancing their mathematical knowledge (e.g., Avraamidou et al., 2015; Go et al., 2022). However, in spite of its potential for students' learning, DGBL has a relatively low adoption rate by teachers (Rüth et al., 2022). Teachers play a crucial role in the implementation of this pedagogical strategy. The research on DGBL demonstrates that it is important that teachers use various pedagogical activities when they implement DGBL in classrooms (Bado, 2012; Foster & Shah, 2020). Furthermore, the literature review reveals a dearth of studies that examine the teacher's pedagogical moves during DGBL mathematics instruction. Therefore, the primary objective of this paper is to examine the implementation of DGBL in mathematics classrooms and analyze the teacher's pedagogical moves during this process. The following research question has been posed: How does the teacher incorporate digital games into the classroom instruction?

THEORETICAL BACKGROUND

Teachers who want to use DGBL in their practice face numerous challenges. For instance, when attempting to incorporate games into instruction, games quite often do not correspond with the required curriculum or the traditional classroom routine. The effort that is needed to adapt the instruction may explain the gap between their desire and actual use of games in the classroom (Foster & Shah, 2020). In some cases, teachers learn how to teach using games through informal means, such as trial and error or by asking their peers for advice (Takeuchi & Vaala, 2014). Foster & Shah (2020) note that such learning is not unexpected given the lack of progress in the field to develop and test systematic models that capture teachers' knowledge of DGBL and to support pre-service and in-service teachers with appropriate professional development opportunities. To realize the full potential of DGBL as an educational strategy, teachers must comprehend the pedagogical aspects of game implementation and develop the appropriate DGBL competencies.

The study of teacher DGBL competencies and game-based pedagogy is currently underway. However, some researchers offered frameworks that describe what these concepts should entail. Nousiainen et al. (2018) consider competences as a multi-layered concept comprising cognitive,

skill-based, and affective components of knowledge, skills, attitudes, values, and ethics. They identified four areas of teacher DGBL competences: *pedagogical* (curriculum-based planning, in-game tutoring, and assessment), *technological* (overcoming technological barriers and analyzing technological tools), *collaborative* (teachers' capacity and willingness to share and communicate content, ideas, and practices), and *creative* (ability to take a playful stance, explore, and improvise). When it comes to educational games, pedagogical competence entails activities specific to DGBL and the educational context such as framing the game within the curriculum and in-game tutoring. Kangas et al. (2017) refer to planning, orientation, playing, and elaboration activities. Developing a pedagogical framework for game-based learning requires planning. During the *planning* phase, a teacher may wonder how the game relates to the rest of the instruction and how gaming situations are structured. During *orientation*, the teacher introduces the game, the gaming process, and the pedagogical objectives of the game. During *playing*, the teacher serves as an active tutor and guide, facilitating and scaffolding student learning. Activity evaluation and reflection are required for *elaboration*. Elaboration, the final step of the DGBL process, is crucial for the learning process because it allows teachers and students to discuss the game, clarify, and reflect on what they've learned (Bado, 2022).

GAME PROBCHALLENGE

There is a wide range of commercial games aimed primarily at the entertainment market, but there is also a growing body of educational digital games. These can serve as a platform for solving problems, for exploring a model of some facet of our world, for fostering collaboration and role play, and so on. Complex game designs typically require sizable development budgets, which are out of reach for most elementary schools and educational researchers. We followed Es-Sajjade & Plaas (2018) stance that a simple game designed specifically for mathematics and informed by established educational theories could produce the desired educational effect. Therefore, within Erasmus+ project called GAMMA (GAme-based learning in Mathematics), we designed a game called ProbChallenge. ProbChallenge game was developed as a collaborative initiative in which researchers, educators and teachers teamed up with one game-designer to build a game intended for upper-secondary mathematics. The intention behind ProbChallenge was to design a digital game that is intended for learning new mathematical concepts, and not only for practicing already learnt mathematical content. The development of the game was framed in Alleven et al. (2010) model for educational-game design. The model combines the MDA-framework for game-design (Mechanics, Dynamics and Aesthetics) with learning objectives and Instructional Design Principles. We describe the game within this framework. The game ProbChallenge is a single player narrative game. According to the story of the game (*aesthetics*) the player is an intern who comes to work in the laboratory (Figure 1) and needs to learn about probabilities to become an equal member of the laboratory. During the game the player engages in game mechanics that are aimed at supporting the player in getting acquainted with basic concepts related to probability such as and calculates probabilities. The game has five levels. The player can choose which of the first four levels he wants to play, while for the fifth level he must achieve a certain result in the fourth level. The first level is the easiest and the player is introduced to the basic concepts needed in the following levels. Each level is more difficult than the previous. The game gives feedback for the entered answer (*dynamics*). After the level is played, the player receives feedback on his performance. The game also has a glossary.

The following learning objectives can be achieved with the GAMMA ProbChallenge: determine the sample space and possible outcomes, describe certain and impossible events, calculate the probability of an event, use the classical definition of probability, calculate the probability of

intersection, union, and complement. Levels 1-4 are required for learning, while Level 5 is for practicing. Instructional design principles involved include findings from cognitive load theory such as employing worked examples, avoiding animations because of negative effect on working memory and different types of information in combination—a picture plus narrative (Sweller et al., 2019). The game can be downloaded from Google Play and the Apple Store.

METHODOLOGY

In this research we utilize case study design. The participant is a Croatian high school mathematics teacher who will be referred to as Mr. T. He is open to professional development and participates in a variety of national and international projects for teachers, such as Erasmus projects. Mr. T has over ten years of professional experience. He got a job at the school as soon as he completed his studies, and he is young enough that technology and its use are not a problem for him in both his personal and professional life. Mr. T joined the GAMMA project because he had previously used playful learning and teaching in classes, primarily non-digital games or gamification using existing applications such as Kahoot for student competition, Genially for escape rooms, and Quizizz for independent practice. He participated in the development of the GAMMA ProbChallenge game but has not yet been involved in professional development related to game-based learning and its classroom implementation. He was chosen as the participant of the study because he decided to use the game GAMMA ProbChallenge with his students.

Observation was chosen as the method of data collection because we wanted to collect information regarding the practical application of digital games in classroom settings. A lesson observation form was used to this end. The lesson, which lasted 40 minutes, was video recorded which allowed for a more detailed analysis on the teachers' pedagogical activities. During the lesson the first author wrote field notes, which consisted of both descriptive information and reflective information (Tenzek, 2017). Description information consists of factual data, such as time, date, setting, and descriptions of situations, while reflective information features the researcher's reflections about the observation. During the video analysis a two-minute observation period was used. The following descriptive information was recorded: (i) whether the teacher interacts with the students; (ii) whether he gives instructions to the entire class or to only some students; (iii) what kind explanations he gives (related to the game or mathematics); (iv) whether he answers the students' questions, and/of monitors the students to see what they are doing.

The observation was conducted openly; the participants were informed of the objectives to build trust, prevent a sense of deception, and make it more acceptable for the researcher to record the students' work and discussions during the observation. During the observation, the students were completely at ease, and their behavior did not indicate any discomfort due to the camera presence. They also did not hesitate to ask the teacher some questions when they encountered obstacles. Therefore, we believe that the researcher did not influence the behavior of the participants and that the classroom situation was genuine.

The observational data were coded and analyzed in relation to Kangas' et al. (2017) framework on pedagogical activities. Therefore, each assigned code was examined and clustered into either planning, orientation, playing, or elaboration category:

Planning:

> Teacher wonders how the game is linked to the rest of the instruction and how gaming situations are organized. He/she determines when, how, and why to use digital games, as

well as how knowledge is shared, created, and validated among students. This includes organizational aspects, such as determining the learning, and gaming groups.

Orientation:

The teacher begins the gaming session with an introduction and provides context regarding the goals of gaming. This phase entails introspection and familiarity with the topic and anticipated learning outcomes.

Playing:

The teacher serves as an active tutor and guide who supports and scaffolds student learning. This can include the following: teacher stops the game for a while and initiates conversation about the topic; asks specific questions during the game aimed at focusing the students' attention on the concepts they were to learn by playing the game; the teacher stops the game to discuss with students the choices they had made during the game.

Elaboration: reflection and evaluation of activities

The teacher discusses the game content after the gaming situations and in this way connects the learning experiences gained in the games with the curriculum and learning. It can include activities where students use elements of what they learned in the game and expand and transform them by relating other information to it.

Example of data analysis is given in the table below (Table 1).

Table 1. Data analysis

Field notes	Lesson	Codes	Category
Teacher talks to the class, announces goal of the lesson	2 min	Lesson goal	Orientation
Teacher asks students if they used probability in their life. Fours students give examples	4 min	Lesson goal	Orientation
Teacher announces to the whole class that they will play the game related to probability and shows how the game is played.	6 min	Lesson goal Game instruction	Orientation
(…)	(…)		
Teachers walks around classroom; students are playing Level 1	16 min	Playing	Playing

RESULTS

In this part, we present the results of the lesson observation in which we observed how the teacher implements a digital game in the teaching of mathematics. We have identified following game-based pedagogical activities within the lesson:

Pedagogical activity Planning:

Mr. T decided to use the digital game GAMMA ProbChallenge when it was time for the Probability topic in the curriculum. He intended to teach the following concepts: sample space, outcome,

equally likely events, possible event, impossible event, certain event, and calculating the probability of simple events The teacher installed the game on the students' computers prior to the lesson. Students sat in groups of four during the lesson, with two students sharing a single computer. It was expected that students would collaborate to solve game-related tasks during game play. This seating arrangement was designed prior to the actual class, as the students were greeted by that arrangement when they entered the classroom. According to Kangas et al. (2017), this pertains to the pedagogical task of planning. During the lesson preparation, Mr. T also created a digital worksheet for students' reflection after game play and paper worksheets for assessing students' understanding of learned concepts. Also during planning, the teacher decided that students should solve the digital worksheets collaboratively, whereas the paper worksheet should serve as a formative evaluation of their knowledge at the conclusion of the lesson and required independent work.

Pedagogical activity Orientation:

At the beginning of the lesson, Mr. T introduced students to the lesson objectives. First, he asked students if they ever heard about probability and about its application. Several students gave answers related to use of probability: weather, gaming, sporting bets. Then the teacher announced they will play a game with two levels. The teacher gave instructions about gameplay: how the game should be played, demonstrated navigation through the game and the activities that follow each level.

Pedagogical activity Playing:

While students played Level 1 of the GAMMA Probability Game, Mr. T circulated throughout the classroom, available to assist anyone who needed it. Students discussed the task with one another or within the group but did not ask the teacher for clarification or assistance.

The teacher also circulated throughout the classroom as students played Level 2 of the game. Students at this level posed questions and initiated conversation by asking questions. Some questions were of a technical nature, such as why the game does not offer more than two chances to answer the same question after an incorrect response has been given. Some questions in the game concerned mathematics, such as whether probability could be greater than 1. Each group of students had questions, and the teacher visited each group and spoke with them individually (for example see Figure 2).

Pedagogical activity Elaboration:

After each level was played (game play happened two times) students had to fill out a digital worksheet in pairs. The worksheet contained the task *3-2-1,* which is meant for reflection. The students must write *three key terms* they learnt in the game, *two concepts* they think they have mastered and *one skill or concept* they would like to master. Both times we observed students calling the teacher and asking him what they should write. Some students commented among themselves: "What else should I write?", "What should I learn better?", "What is the third key concept?". The first time the teacher stopped the class. He acknowledged that this task could be difficult for students but also that he expected them to do it without his help.

After the 3-2-1 task for Level 2, the students were presented with a worksheet with game-related concepts. This task required students to to use the mathematical concepts encountered in the game. Each student individually completed this worksheet. When the teacher distributed the worksheets, some students began to answer the questions, but the bell soon rang, ending the lesson.

Figure 1. screenshot game

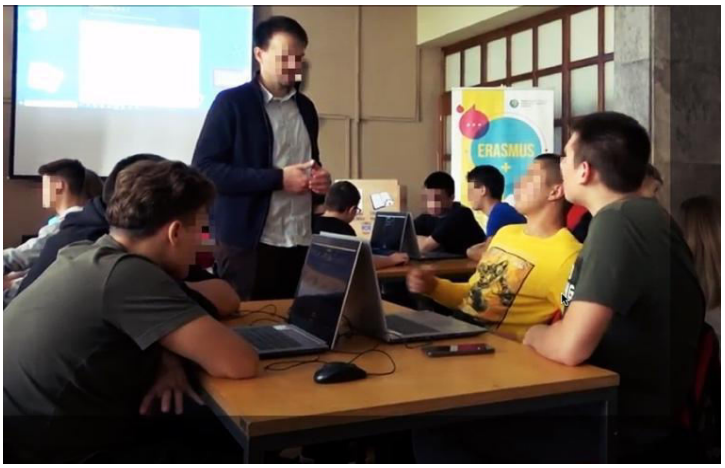

Figure 2. Teacher and students during the lesson

DISCUSSION AND CONCLUSION

The purpose of this study was to investigate implementation of DGBL in mathematics lesson. In particular, the pedagogical activities performed by one mathematics teacher when trying to incorporate digital games into the classroom instruction. The case study presented in this paper illustrates 1) how a well thought lesson with DGBL can support the learning of probability and the pedagogical activities involved; and 2) two factors that have constrained students' learning of mathematics. Namely: lack of support in the elaboration phase in DGBL and time constraint component for the lesson.

Teachers need to take on a new set of responsibilities when facilitating gaming in the classroom. They must act as game administrators, lecturers, game tutors, subject matter anchors, and authority figures to keep students in an educational mode of play during a typical gaming session (Marklund & Alklind Taylor, 2018). In the case of subject matter, it is the responsibility of the teacher to ensure that all students meet the lesson learning outcomes. This indicates that the teacher must play an active role in the DGBL lesson and that digital games are intended to assist teachers in enhancing student participation and learning outcomes and not to replace teachers (Ke, 2016). In the case of Mr. T, four distinct DGBL pedagogical phases were identified: planning, orientation, tutoring during game play, and elaboration. However, the results show the difficulties experienced by the teacher and students namely in the elaboration and reflection phase of the DGBL process. Students had difficulty in 'extracting' the learning content out of the game. The teacher could not provide other support to the students than letting the students figure it out for themselves. Partially because he did not know what to do and partially because the lesson ended. Thus we may consider that the elaboration phase did not occur. Although Mr. T's activities in the elaboration phases were intended to reformulate and transform knowledge and the game played, we believe that the post-game discussions with the students would lead to a more grounded understanding of the probability concepts taught in the game. Mr. T performed his role as facilitator almost admirably up until the elaboration phase, which suggests he is unaware of the significance of group discussion. Bado (2022) and Kangas et al. (2017) highlighted the importance of this lesson phase in DGBL: game

elaboration and reflection, or debriefing, is the transformation of gameplay into learning outcomes; teachers and students should discuss game content, gameplay, and curriculum to establish connections.

The final phase of the lesson appeared incomplete because time ran out and the teacher did not receive student knowledge feedback. This confirms the findings of various studies (e.g. An & Cao, 2016; Kaimara et al., 2021) in which the time constraint was identified as a barrier for DGBL. The formative assessment of students' knowledge must be incorporated into the DGBL lesson, and this must be considered when planning the lesson, as it is essential for the teacher's future work. Additionally, students should have the opportunity to test their understanding of the adopted concepts.

Mr. T's participation in the design of the classroom game can be viewed as gaining experience with game-based pedagogy (Nousiainen et al, 2018). Nonetheless, the lack of collaborative discussion during the elaboration phase demonstrates lack of adequate skills and knowledge in game-based pedagogy. Scholars argue that teacher education in game-based learning is crucial for the effective and meaningful use of games as an educational tool (e.g. Foster & Shah, 2020). According to the findings of Meletiou-Mavrotheris and Prodromou (2017), DGBL training should incorporate both experiential and theoretical learning. We advocate for DGBL professional development that includes knowledge on game elements (such as the MDA framework), learning process and the relation among them because otherwise it is not possible to connect the story, mechanics and dynamics in the game with the mathematical content, procedures and learning experience.

There is a dearth of research on the extent to which mathematics teachers use digital games, how they use them in the classroom, and what obstacles stand in the way of their use of these games (Denham et al., 2022). Our case study adds to the body of research in the area. To develop an appropriate pedagogy for the implementation of digital games in mathematics education, additional research on how teachers utilize DGBL in mathematics classrooms is required.

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