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Is Digital Game-Based Learning Possible in Mathematics Classrooms?

A Study of Teachers' Beliefs

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ABSTRACT

The literature reports that while digital educational games are used in the elementary classroom, they are rarely, if ever, used in the upper secondary mathematics classroom. In order to investigate this situation, a survey was conducted to determine what upper secondary school mathematics teachers think about digital games and what obstacles and limitations they perceive in using DGBL as a teaching approach. The results indicate that mathematics teachers view digital games as a useful teaching tool; however, the lack of knowledge about teaching with digital games and shortage of appropriate games for teaching upper secondary mathematics seems to discourage them from using them as a main teaching tool. These findings imply that professional development should be designed with a focus on teacher training. Furthermore, the development of constructionist-based games should be considered, where games are based on meaning-making rather than practicing mathematical content, as has previously been the case.

KEYWORDS

Barriers, Classroom Implementation, Digital Educational Games, Mathematics Instruction, Upper-Secondary Mathematics Teachers

INTRODUCTION

Over the past two decades, mathematics education has been rethought in the context of integrating digital technologies into the classroom. This has led to an apparent need to change the way mathematics is taught, away from siloed and fragmented traditional approaches towards integrated, interdisciplinary, and holistic approaches. Digital game-based learning (DGBL), an approach introduced by Mark Prensky (2001) as a descendant of game-based learning (GBL), can be a powerful tool in supporting this transformation of mathematics education. DGBL is a learning approach based on the idea of

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using digital games for educational purposes. Moreover, DGBL is also associated with important 21st century skills such as critical thinking, creativity, problem-solving, agency, collaboration, communication, and digital literacy (Gee, 2005; Williams-Pierce, 2019).

While DGBL has gained popularity in research in recent years (Byun & Joung, 2018; Fadda et al., 2021; Coleman & Money, 2020; Hussein et al., 2022), little attention has been paid to the opportunities it can provide for upper secondary mathematics. Mathematics in upper secondary grades is abstract, often lacks meaningful contexts, and is associated with negative student attitudes such as lack of motivation, disengagement, and lukewarm interest (Ashcraft, 2002; Hannula, 2002). Integrating DGBL practices into secondary mathematics classrooms in a fruitful way, where students take an active role in their learning process, could be an essential pedagogical strategy to address this long-term problem. However, a significant issue with DGBL in general is the relatively low rate of adoption among teachers who continue to use traditional approaches and tools for teaching mathematics (Rüth et al., 2022). Teachers play a key role in bringing this approach into practice, thus to a certain extent their opinions and beliefs are the starting point for developing and implementing digital games for teaching mathematics at the secondary level. The purpose of this study is to explore upper secondary mathematics teachers' perspectives on the challenges and barriers related to implementing DGBL in their classrooms.

THEORETICAL BACKGROUND

Digital Educational Games and DGBL

This section distinguishes between educational or serious games, entertainment games, and gamification in order to explain the authors' stance on the position of digital educational games, as despite their similarities, these terms are not interchangeable. Digital games, also called video games or computer games, are played on a computer, game console, smartphone, or tablet (Fadda et al., 2022). Educational games combine learning with gameplay (Hussein et al., 2022). To distinguish them from entertainment games, in the gaming industry educational games are referred to as serious games. Serious games often use graphical simulations of reality to meet learning or training goals for a specific stakeholder or user group (Martens & Muller, 2016). However, serious games may also be designed for purposes other than education, such as behaviour change or therapy. Thus, two terms came to existence: applied games and educational games. Because the applied game does not necessarily teach (e.g., applied games may be used for healthcare), we will use the term digital educational game for games used in an educational context where the intention is to learn rather than to have fun. The term gamification describes the utilization of game design elements in non-game contexts (Deterding et al., 2011). Gamification is often limited to points, badges, levels, and leader boards. Some scholars view gamification more broadly. For instance, Chou (2019) identifies eight core drives—epic meaning, accomplishment, empowerment, ownership, social influence, scarcity, unpredictability, and avoidance—that can be found in various games. These drives may inspire the gamification of other activities. This paper examines the use of digital educational games as opposed to the use of gamification. DGBL is seen as a student-centred approach in which educational goals and content are incorporated into games to encourage students to learn and advance their knowledge and skills by providing an engaging learning environment.

Teacher Perceptions and Barriers to Using Digital Educational Games

New technological developments have prompted the creation of digital educational games that are intended to complement learning as well as be incorporated into teacher practices and curricula (Callaghan et al., 2018). However, teachers' instructional practices are guided by what they believe about mathematics and the teaching and learning of mathematics (Liljedahl, 2008; Thurm & Barzel, 2022). Thus, what constitutes a DGBL environment in the school is closely related to how teachers think about games. This includes their beliefs on the efficacy of games, what games can and cannot do, and how games should or should not be used (Beavis et al., 2014). The way teachers work with games has a direct impact on the success or the failure of DGBL initiatives. Studies have found that many teachers do not believe in the transformative potential of digital games in the classroom and many of them believe they are ill-prepared to use them effectively (e.g., Easterling, 2021; Ertmer et al., 2012; Kaimara et al., 2021; Warwick, 2019). Perceived usefulness and ease of use have been found to be important factors in teachers' intentions to use technology (Bourgonjon et al., 2013). Specifically, teachers' intention to teach with digital games has been found to be positively related to the perceived usefulness of digital games (Huizenga et al., 2017). When teachers believe games can develop mathematical competency, they are more likely to endorse positive attitudes towards them (Yeo et al., 2022).

Teachers encounter numerous obstacles when they attempt to incorporate games into instruction. This may explain the gap between teachers' desire to use games and the practice of using them for teaching and learning (Shah & Foster, 2015). Significant obstacles for teachers include a mismatch between the knowledge and skills embedded in the game and those explicitly identified by the curriculum, a lack of ICT skills, and a reluctance to use games in the classroom (Papadakis, 2018; Sánchez-Mena & Mart-Parreo, 2017; Scherer et al., 2021). Teachers indicate that there is a lack of professional development opportunities that could systematically guide them in how to use digital games to teach, learn, and assess (Fishman et al., 2014; Martin-del-Pozo et al., 2019; Spiteri & Chang Rundgren, 2020). The effect of which means that they do not possess the expertise needed to incorporate games into their lessons (Takeuchi & Vaala, 2014; Project Tomorrow, 2019). Related studies have shown that teachers, even if they find digital games fun or potentially useful for learning, tend either to avoid their adoption as a teaching tool or use rather simple forms of games such as drill-and-practice or trivia games in their classes (Jesmin & Lay, 2020; Takeuchi & Vaala, 2014). In addition, teachers note that the absence of an educational policy impedes the implementation of DGBL in the classroom (Kaimara et al., 2021). Budget constraints also limit schools' ability to acquire high-quality educational games and adequate technical equipment, which in turn hinders their capacity to implement DGBL (Baek, 2008; Kaimara et al., 2021; Li, 2017).

Only a few studies were found in the literature that addressed upper secondary school mathematics teachers' perceptions and experiences of DGBL (Deng et. al., 2020; Torres Castillo, 2019). This is contradictory from a pedagogical standpoint, given the significance of developing and studying DGBL practices to fully realize their potential for enhancing mathematics instruction. Thus, it appears crucial to take teachers' beliefs seriously, as the efficacy of their teaching practices is inextricably linked to their perspectives on DGBL and their own experience with digital educational games in their mathematics classrooms (Bourgonjon et al., 2013). Digital games and DGBL must be seen as valuable for teaching and learning by teachers in order to be an effective tool in mathematics education.

Literature Review: What can be Achieved With Digital Educational Games in Mathematics

Mathematics teaching can only be said to be truly effective if it has a positive impact on students. Pan et al. (2022) conducted a systematic review of the literature to better understand the role of digital educational games in K-12 mathematics. The review included studies that were published between 2008 and 2021 and were experimental in design in some way. According to the findings, DGBL was most beneficial for students' working memory, then knowledge and skills. The analysis revealed that digital mathematics games were frequently used as a supplementary teaching tool for practicing, whereas learning new content was only reported in a small number of studies. Action, puzzle, and strategy games were the most frequently used when the learning objective was to enhance students' computational fluency. These games used time-limited in-game competitions. Role-playing, adventure, simulation, and construction games were used to help students achieve higher-order cognitive learning outcomes. These games often used experiential learning.

Another study examined DGBL applications in K-12 mathematics education to assess the effects on knowledge, perceptual and cognitive skills (Hussein et al, 2022). The authors examined only quasi-experimental and randomized control trial studies in order to determine the effect of DGBL compared to other teaching methods. The review included studies published between 2008 and 2019. The findings showed that DGBL was used to teach a variety of mathematics-related topics, but the main focus was on arithmetic operations. The findings also showed that most studies (22 out of 27) showed that DBGL had a positive impact on students' knowledge, and that seven out of nine studies had positive results on perceptual and cognitive abilities.

In addition to cognitive gains, such as knowledge, digital games can have an influence on the affective characteristics of students. Motivation is an important factor in the learning process and sustaining students' motivation in mathematics is a significant challenge for teachers. Digital games better promote motivation than traditional teaching practices (Fadda et al., 2022), and make learning more interesting and fun (Siew, 2018; Es-Sajjade & Paas, 2018). In a recent study, researchers compared commercial apps marketed as educational games with interactive digital worksheets for the same primary school mathematics content (Gresalfi et al., 2018). The learning outcomes for the apps were similar to those for the worksheets, however, students found the games to be more interesting than the worksheets. Moreover, digital games positively influence students' affective and behavioural change towards mathematics (Hussein et al., 2022).

Mathematics anxiety is a persistent type of anxiety that affects one in six students (Hill et al., 2016), this condition is more prevalent among girls than boys (e.g. Luttenberger et al., 2018). In the past ten years, DGBL has been proposed as a potential treatment for maths anxiety based on positive findings from closely related research fields. A significant reduction in maths anxiety was observed when DGBL encouraged collaborative and social interactions (Dondio et al., 2023). Furthermore, digital games proved to be an effective tool for closing the gender gap in middle school mathematics education (Nguyen et al., 2023).

Recently, greater efforts have been made to create digital educational games with the content and outcomes desired by teachers (Callaghan et al., 2018). Joung and Byun (2021) conducted an exploratory study to evaluate the quality of digital maths games by measuring how much the content of a digital game is aligned to the NCTM standards. Their analysis showed alignment of games with process standards and number and operation content standards. Pan et al. (2022) found that that state curricula, state assessment standards, and national council standards are aligned with the content of maths games in the studies included in their systematic review.

The reviews on DGBL in mathematics (Pan et al., 2022; Hussein et al., 2022; Byun & Joung, 2018) revealed that the majority of studies employed drill-and-practice games. Furthermore, most existing studies pertain to primary or lower secondary education (Pan et al., 2022; Hussein et al. 2022; Byun & Joung, 2018; Chan et al., 2023). One reason for this may be related to primary or lower secondary mathematics concepts and procedures that are easily implemented in practice and training games. Integrating complex topics from upper secondary school mathematics, on the other hand, may be more difficult. Nonetheless, digital educational games seem to be a promising teaching tool making the learning of mathematics more engaging and fruitful because of features such as instant feedback, learning from mistakes, active learning, experiential learning, and problem-based learning (Chen et al., 2020).

Research Focus

According to the literature review in the preceding sections, the use of digital educational games by upper secondary mathematics teachers has not been extensively researched. There is a need to investigate whether these teachers use digital games in the classroom, if so, which parts of the lesson they use them in, and what obstacles they face. In this way, not only can we gain insight into mathematics teachers' attitudes towards and expectations of DGBL, but also any misconceptions they may have about it. Consequently, the data collected can inform the development of digital educational games for upper secondary mathematics, the design and implementation of professional development activities, and the creation of materials that can help teachers in classroom practice. With this in mind, a survey was conducted targeting upper secondary mathematics teachers. The following research questions are posed:

What attitudes do upper secondary mathematics teachers have towards existing digital games for teaching mathematics? What hinders teachers in implementing DGBL in mathematics teaching?

METHODOLOGY

Context, Participants, and Data Collection

The study presented in this paper is part of the Erasmus+ project GAMMA (Game-based learning in mathematics), which aims to develop digital games suitable for use in upper secondary mathematics, design accompanying learning scenarios for the implementation of the digital games developed, and produce a mathematics teacher's handbook on DGBL. The project included researchers and teachers from four countries: Croatia, Finland, Greece and the Netherlands. In order to produce the abovementioned outputs, the project members analysed and compared the mathematics curricula of the participating countries. The results revealed that the Greek and Croatian mathematics curricula share 90% of the expected learning outcomes. Since the purpose of the study was to gain insight into mathematics teachers' perspectives on digital games, the authors decided to conduct a survey among Greek and Croatian secondary mathematics teachers. The study was conducted in the spring of 2021, when schools were closed intermittently due to the pandemic. The convenience sampling was used. Given the work overload teachers experienced during the periods of remote learning and the saturation of online work, the most efficient way to collect data was to contact teachers who were already familiar with GAMMA project members, who taught or lectured at mathematics education professional development workshops and conferences. The authors of the study believed that this would ensure truthful responses to the questionnaire. Emails were sent to potential participant teachers to determine whether they use digital educational games in their teaching and whether they were willing to participate in the study. A link to an online survey was provided to teachers who agreed to participate. Quota sampling was used to ensure that the number of teachers in both countries who use digital games in mathematics classrooms was equal to the number of teachers who do not (Cohen et al., 2017). This way, no group would be underrepresented. Overall, 284 upper secondary mathematics teachers participated in the study, where 50% of teachers use digital games in mathematics lessons and 50% do not use digital games Participants were also asked socio-demographic questions that provided information on their gender, years of service, career advancement, and the type of school they work in (Table 1). Throughout the paper the teachers who use digital educational games in the classroom are referred to as game adopters, while those who do not use games are referred to as non-adopters.

Responses were recorded anonymously and participation in the study was on a voluntary basis. The questionnaire, which took approximately 15 minutes to complete, examined teachers' attitudes and opinions regarding digital games, such as their willingness to use games in upper secondary mathematics classrooms as well as obstacles that impede their use.

Instrument and Data Analysis

The questionnaire was inspired by Ince and Demirbilek's (2013) study, which investigated teachers' perceptions and attitudes towards digital games in general. Based on findings from the literature review, a set of items was developed to assess mathematics teachers' perceptions of digital games in general (adapted from Ince & Demirbilek, 2013), effectiveness of game utilization for teaching mathematics (adapted from Ince & Demirbilek, 2013; with input from MSE, 2019, MERA, 2021 and NCTM, 2014) and accessible resources (adapted from Baek, 2008). A group of project members from both

Table 1. Information about the participants

Participant Information	*n*	%
Game Adopters	142	50%
Non-Adopters	142	50%
Gender		
Female	218	77%
Male	66	23%
Type of school		
Grammar	139	49%
Vocational	145	51%
Teaching experience		
< 5 years	37	13%
6-15 years	85	30%
16-25	77	27%
26-34	65	23%
35+	20	7%
Teacher promotion		
No promotion	153	54%
Teacher mentor/adviser	131	46%

countries, including researchers and upper secondary mathematics teachers, reviewed the adapted items and agreed on relevant and important items. The final version of questionnaire included 26 items.

To avoid any misunderstanding, the survey included an explanation of what the authors considered to be a digital educational game (as opposed to, for example, gamification). Items were set in a linear numerical response format from 1 to 5, with 'strongly disagree' at one end and 'strongly agree' at the other. Anchor points were placed only at the extremes; no anchor points were set for the midpoints. Such items can be treated as continuous data in statistical analysis (Vickers, 1999; Harpe, 2015). The items were designed in English and then translated by the authors into the native language of the study participants.

This study does not seek to compare Croatian and Greek teachers' beliefs about DGBL, but to investigate what game adopters and non-adopters think about digital (educational) games, what obstacles they perceive, and what resources they need. Accordingly, the teachers' attitudes were analysed as attitudes and opinions of upper secondary mathematics teachers regardless of which country they are from. Descriptive statistics, factor analysis and *t*- test were used. The reliability of the whole questionnaire was 0.906. Factors were extracted using the principal axis factoring method, and the initial factors were orthogonally rotated using the varimax method, because there were no theoretical bases to which the factors in this study were correlated (Henson & Roberts, 2006). All tests were performed at a significant level of $\alpha=0.05$. Statistical analyses of quantitative data were performed using IBM SPSS Statistics.

RESULTS

Table 1 displays descriptive data for each questionnaire item separately, including mean scores and standard deviation. In addition, mean scores and standard deviation are provided based on whether teachers use digital games in the classroom. The results presented in this manner offer a glimpse into the perspectives of mathematics teachers on the various aspects of digital educational games that were investigated. The mathematics teachers' attitudes towards digital games in general are not negative. They do not believe that playing digital games interferes with social life or takes up an excessive amount of time (Item 1 & Item 2). Importantly, they do not view games as a medium for young children only (Item 3). The results for games adopters and non-adopters are comparable for these items, indicating that the teacher's familiarity with existing digital games has no effect on their positive attitudes towards games in general. Teachers in the study indicated that the available technology in schools can be a significant barrier to DGBL. Technology was mentioned by both groups of teachers as a potential barrier to using digital educational games in the classroom (Item 15). Although many students today own smartphones, not all mathematically themed educational games are compatible with such devices. This item could be linked to financial resources for purchasing equipment or digital games (Item 16). Teachers have indicated that the available funding falls short of their needs, which could have an effect on the availability of commercial educational games. Other items examined specific attitudes tied to exclusively teaching mathematics and will be explored in the text below.

Exploratory factor analysis (EFA) was conducted using the principal axis factoring (PAF). Initially, all items were examined, which resulted in the recoding of items that had negative loadings. Data adequacy was tested using the Kaiser-Meyer-Olkin and Bartlett test (0.89, $p < .0001$). Items with a commonality of less than 0.4 were excluded from further analysis (items 1, 2, 3, 16 &15). Four factors were retained whose eigenvalues were greater than 1. The factors obtained explained a total of 67.46% of the variance in the manifest variables. The internal consistency of factors, measured with Cronbach's α, equals 0.946, 0.805, 0.805 and 0.705 respectively. The four-factor structure of the questionnaire on mathematics teachers ' attitudes towards digital educational games can be seen in Table 3.

Items in which the first factor is highly saturated represent teachers' opinions on whether digital educational games can be used for teaching mathematics to accomplish the goals of mathematics education and achieve cognitive or affective learning outcomes specified by the mathematics curriculum. Thus, the first factor was labelled *Mathematics instruction*. The second factor, *Resources*, contains items pertaining to various resources vital to DGBL in mathematics. Resources can be thought of as everything associated with teacher practice, including teacher knowledge, professional development, digital educational games, and materials accompanying games, as well a list of suitable digital mathematics games which should be provided by the stakeholders. The third factor includes the opinions and beliefs of the mathematics teachers regarding time and curriculum constraints that affect DGBL - this factor is labelled *Time and content constraints*. The fourth factor, the *Role of games*, relates to the functions of games in the classroom, such as reward, main teaching tool, and free time activity. Table 4 provides descriptive statistics on the obtained subscales.

Mathematics Instruction (Factor 1)

Regardless of the age of the students, the teachers surveyed believe that digital educational games can be effective for teaching mathematics ($M = 3.90$, $SD = 0.85$, Table 4). In this type of instruction, classroom management does not appear to be an issue. In addition, mathematics teachers believe that DGBL can be used to achieve the goals of mathematics education, such as reasoning, problem-solving, and mathematical communication (e.g. MSE, 2019; NCTM, 2014). They see digital educational games as a way to help students cultivate positive attitudes and perseverance when dealing with difficult tasks, as well as a way to help them achieve the learning outcomes set out in the mathematics curriculum. It appears that teachers recognize the benefits of digital games, which is consistent with the description of the promising potential of DGBL in the literature. Despite the fact that questions on the potential of digital games should be viewed as conditional and that positive responses do not necessarily correspond to them becoming a part of classroom practice, they show a significant

Table 2. Descriptive data

	Items	M (SD)	GAs M (SD)	N-As M (SD)
1	Playing digital games affects people's social life negatively.	2.79 (1.07)	2.70 (1.02)	2.89 (1.19)
2	Playing digital games is time-consuming.	3.37 (1.05)	3.30 (1.04)	3.47 (1.05)
3	Playing digital games is only for young children.	1.99 (0.93)	1.94 (0.82)	2.07 (0.94)
4	Digital educational games are effective for teaching mathematics when used as an auxiliary tool for teaching mathematics.	4.13 (0.96)	4.35 (0.89)	3.84 (0.97)
5	Digital educational games can be effective for teaching mathematics when they are based on realistic goals.	4.00 (0.94)	4.16 (0.89)	3.78 (0.94)
6	Digital educational games can be effective to teach mathematics when used as a main tool for mathematics instruction.	2.17 (1.12)	2.33 (1.24)	1.97 (1.03)
7	Digital educational games can be effective for learning mathematics when used as a reward in class.	3.15 (1.23)	3.21 (1.37)	3.05 (1.21)
8	Digital educational games can be effective for learning mathematics when used to fill free time of students in mathematics class.	3.19 (1.38)	3.24 (0.90)	3.12 (1.39)
9	Digital educational games can be applicable to all grade levels.	4.08 (1.04)	4.31 (0.95)	3.78 (1.08)
10	Digital educational games can be used to support mathematics education goals such as problem solving, communication, reasoning, making connections, and using mathematical representations to model and interpret practical situations.	3.98 (1.02)	4.21 (0.96)	3.69 (1.03)
11	Digital educational games can help fulfil learning outcomes defined in mathematics curriculum.	3.90 (0.99)	4.11 (0.89)	3.62 (1.03)
12	Digital educational games can help students develop a positive attitude towards mathematics and become active learners and problem solvers.	3.82 (0.99)	4.03 (0.96)	3.53 (0.97)
13	Digital educational games are appropriate for teaching mathematics.	3.99 (0.99)	4.22 (.093)	3.69 (.98)
14	Digital educational games do not cause any problems in classroom management during mathematics instruction.	3.51 (1.13)	3.79 (1.15)	3.14 (.98)
15	Existing technology in school is insufficient to handle teaching mathematics with digital games.	3.58 (1.15)	3.47 (1.16)	3.74 (1.11)
16	It is difficult to secure financial resources to buy digital educational games and equipment for teaching with it.	3.84 (1.03)	3.79 1.09	3.90 (0.95)
17	The current mathematics curriculum does not permit teaching with digital educational games.	2.59 (1.17)	2.37 (1.13)	2.88 (1.15)
18	The number of hours allotted for teaching mathematics does not allow for teaching with digital educational games.	3.43 (1.189)	3.19 (1.2)	3.72 (1.09)
19	The length of the lesson does not allow for teaching with digital educational games.	3.23 (1.23)	3.05 (1.22)	3.45 (1.19)
20	Teachers have difficulty finding supporting materials for teaching mathematics with digital educational games.	3.34 (1.087)	3.10 (1.11)	3.66 (0.97)
23	There is inadequate professional development support for teachers to teach mathematics with digital games.	3.55 (1.12)	3.36 (1.15)	3.79 (1.03)
24	Education policy has not yet approved a list of mathematics games for teaching purposes.	3.67 (1.02)	3.53 (1.05)	3.83 (0.97)
25	There are few reference materials for teaching mathematics with digital educational games.	3.47 (1.02)	3.31 (1.09)	3.69 (0.89)
26	Most teachers do not have the knowledge to teach mathematics with digital educational games.	3.95 (0.91)	3.80 (0.98)	4.14 (0.78)

GAs = game adopters; N-As = non – adopters

Table 3. Four-factor structure on mathematics teachers' attitudes towards digital educational games

	Factor loadings			
	1	2	3	4
Factor 1: Mathematics instruction				
Digital educational games can be used to support mathematics education goals such as problem solving, communication, reasoning, making connections, and using mathematical representations to model and interpret practical situations.	**.908**	.096	.140	.078
Digital educational games can help fulfil learning outcomes defined in mathematics curriculum.	**.871**	.147	.098	.129
Digital educational games can be applicable to all grade levels to teach mathematics.	**.851**	.104	.098	.087
Digital educational games can help students develop a positive attitude towards mathematics and become active learners and problem solvers.	**.850**	.159	.090	.143
Digital educational games are appropriate for teaching mathematics.	**.847**	.110	.178	.168
Digital educational games are effective for teaching mathematics when used as an auxiliary tool for teaching mathematics.	**.817**	.078	.091	.147
Digital educational games are effective for teaching mathematics when they are based on realistic goals.	**.736**	.006	.053	.094
Digital educational games do not cause any problems in classroom management during mathematics instruction.	**.708**	.110	.156	.256
Factor 2: Resources				
There is inadequate professional development support for teachers to teach mathematics with digital games.	.118	**.814**	.080	.023
There are few reference materials for teaching mathematics with digital educational games.*	.171	**.778**	.138	-.052
Education policy has not yet approved a list of mathematics games for teaching purposes.*	.047	**.740**	.083	.071
Teachers have difficulty finding supporting materials for teaching mathematics with digital games.*	.090	**.738**	.138	.046
Most teachers do not have the knowledge to teach with digital educational games.*	.055	**.573**	.130	.053
Factor 3: Time and curriculum constraints				
The number of hours allotted for teaching mathematics does not allow for teaching with digital educational games.*	.159	.212	**.882**	-.006
The length of lessons does not allow for teaching with digital educational games.*	.133	.199	**.877**	-.033
The current mathematics curriculum does not permit teaching with digital educational games.*	.247	.168	**.682**	-.155
Factor 4: Role of the games				
Digital educational games can be effective for learning mathematics when used as a reward in class.	.207	.080	-.004	**.820**
Digital educational games can be effective for learning mathematics when used to fill free time of students in class.	.235	-.029	-.126	**.759**
Digital educational games can be effective to teach mathematics when used as a main component of instruction.	.149	.071	-.040	**.703**

Table 4. Descriptive statistics on obtained subscales

Subscales	α	*n*	M	SD
Mathematics instruction	0.946	284	3.90	0.85
Resources	0.805	284	3.63	0.77
Time and content constraints	0.805	284	3.14	1.03
Role of games	0.705	284	2.91	1.01

M = mean; SD = standard deviation

optimistic outlook. The beliefs and attitudes of teachers are crucial to the selection of classroom resources and their integration. Both groups of teachers, game adopters and non-adopters, have a positive attitude towards digital games for teaching and learning mathematics, and this represents the first major step towards implementing DGBL in their classrooms. However, the hesitancy of teachers, especially non-adopters (Table 5, $p < 0.001$), is evident. The rest of the data will be used to determine what is preventing teachers from using digital educational games in their classrooms.

Resources for Teaching With Digital Educational Games (Factor 2)

The mathematics teachers believe they lack the resources needed to teach with digital educational games (M= 3.63, SD = 0.77, Table 4). By their evaluation, they lack a considerable amount of expertise that would be required to teach mathematics with a DGBL approach. The lack of support from the stakeholders has a significant effect because they are the ones who prescribe the education policy which establishes a standard for teaching, such as the use of a specific method of instruction. There is insufficient professional development available to train teachers in DGBL. The difference between game adopters and non-adopters on these issues is statistically significant (Table 5, $p < 0.001$), particularly in terms of DGBL knowledge and related professional development. In addition to the aforementioned obstacles, non-adopters perceive the difficulty of locating appropriate digital games to be more difficult, which most likely has an effect on their willingness to use them in the classroom.

Time and Content Constraints (Factor 3)

Teachers seem to be undecided whether the length of the lesson and curriculum expectations prevent them from using digital educational games in the classroom (M = 3.14, SD = 1.03, Table 4). However, there is a statistically significant difference between game adopters and non-adopters (Table 5, $p = 0.002$), namely non-adopters perceive lack of time and curriculum requirements in mathematics as greater barriers to DGBL than teachers who already use some form of digital games in the classroom.

Table 5. Comparison of game adopters and non-adopters

	Game Adopters M (SD)	Non-Adopters M (SD)	*t*(284)	*p*-Value
Mathematics instruction	4.07 (0.83)	3.68 (0.83)	3.959	<.001*
Resources	3.47 (.079)	3.79 (0.68)	3.685	<.001*
Time and content constraints	2.99 (1.07)	3.36 (0.94)	3.096	0.002*
Role of the games	2.99 (1.02)	2.79 (0.98)	1.685	0.093

*statistically significant at the level of 0.05

Role of the Games (Factor 4)

Mathematics teachers in the study indicate that they are undecided whether games should occupy the greater part of the mathematics lesson, and whether playfulness should be part of mathematics instruction (M = 2.91, SD = 1.01, Table 4). This contradicts their belief that games are valuable instructional tools for mathematics instruction. On the one hand, this result may be related to teachers' claims that they lack the necessary resources (such as knowledge) to implement DGBL effectively. On the other hand, reluctance to use digital educational games as a main component of instruction may be related to the design of the existing games. Although the teachers indicated that DGBL could be used to achieve effective teaching of mathematics, it seems that the existing digital educational games do not meet their expectations for the effective teaching of mathematics. Moreover, the difference between game adopters and non-adopters is small and not statistically significant (Table 5, $p = 0.093$).

CONCLUSION

This study explored the perspectives of upper secondary mathematics teachers on digital educational games. The reported results show a significant discrepancy. On the one hand, nearly all the mathematics teachers surveyed have a favourable opinion of digital educational games and recognize their potential to enhance mathematics instruction and learning, but on the other hand the findings show that existing games are not thought to have the transformative power required to be fully integrated into their practice. Digital educational games are viewed as supplementary resources that could support established traditional practices, but only if teachers have time. It appears that teachers' expectations regarding digital games do not correspond with classroom realities.

The results show that mathematics teachers' current perspectives are largely consistent with findings from the international literature on mathematics education (Yeo et al., 2022), as well as other educational disciplines (e.g., Baek, 2008; An & Cao, 2016). Similar issues were identified approximately 15 years ago (Baek, 2008). This leads to the question of how active DGBL proponents have been in developing pedagogically oriented digital games as well as training and equipping teachers for DGBL practices.

The findings of this study lead to the following conclusions: In order to change the teaching practices of upper secondary mathematics teachers, such as using digital educational games as their primary instructional tool, appropriate professional development must be created. The study's findings show that professional development should address the purpose of using games, how to align game objectives with the existing mathematics curriculum, how to use game features and integrate games into mathematics instruction In addition to the latter, the teachers should also be equipped with DGBL strategies for interactions with students during and after game play. Without such support, teachers' knowledge of DGBL will be fragmented, leaving them in a difficult position, unsure of how and when to implement it. This is supported by prior research indicating that teachers may not be able to comprehend and implement DGBL effectively in the classroom if they do not receive adequate professional development (Kaimara et al., 2021; Easterling, 2021). Callaghan et al. (2018) discovered that mathematics teachers prefer to participate in teacher training in order to gain DGBL experience under supervision. This seems like a good idea because DGBL is challenging and calls for specific competencies, such as adaptive skills (Foster & Shah, 2020), which may not come naturally to many teachers (Eastwood & Sadler, 2013).

Additionally, there needs to be a shift in the attitudes and beliefs of mathematics teachers; this is both possible and perhaps essential in order to greatly enhance mathematics education. It should also affect the epistemological nature of mathematics education, which is more crucial than ever given the requirements and expectations of the digital society of today and tomorrow. Digital educational games have the potential to transform mathematics learning from a meaningless and decontextualized activity to a meaningful and active one. Using their agency, critical thinking, creativity, and imagination, students can engage with mathematics and develop their own unique meanings (Kyngios, 2019). Obviously, this is not a simple task. Mathematics teachers have the most influence in bringing about this change and they must personally experience the transformative benefits of DGBL as a paradigm shift.

The vast majority of digital educational games replace existing paper-and-pencil practices with drill-and-practice activities in a game environment, with an emphasis on procedural knowledge. For students to engage in meaningful mathematics and mathematical thinking, game designers should seek to transform pedagogical practices and offer transformative experiences (Ainley et al., 2011; Kynigos, 2019). Such transformative games would allow students to engage in mathematical activities in interesting, playful ways, not because of the game accoutrements, but because using mathematics to design or play a game can be creative, interesting, and exciting. Such an open-ended play environment can facilitate conceptual learning approaches (Kynigos, 2019). Moreover, this type of mathematical activity can provide students with opportunities to personalize mathematical concepts.

Constructionism theory (Moon & Ke, 2020; Kynigos, 2015; Papert, 1993) provides a solid theoretical foundation for designing transformative games and analysing the meanings students develop while participating in them. Constructionists have always focused on creating transformative activities in which students can develop their own meanings in mathematics through the construction of meaningful digital artifacts (Girvan & Savage, 2019; Kynigos, 2015; Papert, 1993). According to the constructionist approach, instead of embedding traditional lessons directly into games and producing game-enhancers, students can be given more opportunities to build new relationships with knowledge by engaging in the process of making or controlling a game and using mathematics as a tool (Kafai, 2006; Grizioti & Kynigos, 2020). In constructionist games, players are not only game consumers but also active agents in how the game develops. There have been attempts to design such digital educational games for mathematics using a variety of platforms and focused authoring systems, such as Minecraft, Scratch, E- Rebuild, Alice, or lesser known ones such as ChoiCo, MaLT (e.g. Weintrop et al., 2016; Grizioti & Kynigos, 2020; Kynigos & Grizioti, 2018; Moon & Ke, 2020; Moore, 2018). However, these studies and the games developed centred on elementary or lower secondary mathematics, leaving upper secondary mathematics unaddressed. Although digital educational games with underlying constructionist principles exist, they are not as prevalent in studies and discussions about DGBL (Moon & Ke, 2020; Papavlasopoulou et al., 2017), which is surprising given their potential to support mathematics learning and the development of mathematical skills through the creation of personal, meaningful artifacts in digital environments (Kafai & Burke, 2015). This could in part be because it can take some time and effort to become familiar with constructionist learning environments and activities, however this could be overcome by using a Use-Modify-Create approach to scaffold student learning (Grizioti & Kynigos, 2020). Here students do not start from scratch, but they follow small steps of engagement which transforms them from users to creators able to tackle higher design challenges as their skills and knowledge increase.

The next step is to design mathematics games that incorporate upper secondary mathematics teachers' beliefs and expectations into a new kind of digital game that could lead to rethinking traditional mathematics instruction rather than replacing or reinforcing it. It is reasonable to assume that after experiencing the potential of such digital games, teachers recognize their value for teaching mathematics and would use them as one of their key teaching resources. Technical equipment is important because mobile environments and tablets must support this type of software. Within the Erasmus+ project GAMMA transformative digital games are being developed. The project members will invite teachers to learn about these games and the philosophy behind them and help them use them in their mathematics classrooms. Subsequent to that, the authors will investigate the teachers' beliefs about digital educational games and see whether, and to what extent, they have changed.

All procedures performed in the 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.

CONFLICT OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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