Specific features of implementing digital games in mathematics lessons in secondary schools of Ukraine and Israel

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Abstract

The article presents an analysis of the features of the implementation of digital games in mathematics lessons in secondary schools in Ukraine and Israel, using data clustering methods and graphic analysis. The choice of these two countries is determined by the opportunity to compare educational systems operating under different cultural, socio-economic, and infrastructural conditions, as well as their shared experience of adapting to crisis situations, including state of emergency (including martial law in Ukraine), which has stimulated the search for innovative teaching approaches. The results of the analysis of students' attitudes regarding the possibility of using digital mathematical games in the educational process and their interest in mathematical digital games are characterized. As a result of the study, the growth of interest of Ukrainian students in digital mathematical games was noted. In general, there is a trend towards the introduction of digital games at various levels of education, but there are a number of unresolved important issues, including didactic ones. The study is based on a mixed-methods approach combining quantitative surveys and qualitative analysis using data clustering techniques (DBSCAN, K-means) and graphical interpretation of the results. Using a mixed-methods approach, including quantitative surveys and qualitative analysis (K-means clustering, DBSCAN for cluster estimation, Davies-Bouldin Index, and graphic analysis using Python for visualizations), the research aimed to determine and analyze the features of digital game implementation in mathematics lessons. A comparative analysis of students in Ukraine and Israel revealed a high level of interest in using the digital math games (over 80% of respondents) alongside a low level of actual implementation by teachers. Key findings indicate that while both Ukrainian and Israeli students expressed strong interest in using the digital math games in class (over 80% in both countries), there is a notable gap between this desire and actual teacher implementation. Although there was no direct interaction between respondents from the two countries, the comparative design allowed the identification of common trends and country-specific challenges. The paper proposes stages for integrating digital didactic games into the educational process and identifies key factors influencing their effectiveness and accessibility. The article outlines the stages of integrating digital didactic games into the educational process, from planning and goal setting to testing, evaluation, and implementation. It emphasizes the importance of considering technical features, design requirements, and user feedback throughout the process to ensure the effectiveness and accessibility of these games. The findings highlight that continuous monitoring and collaboration with teachers, students, and administrators are crucial for assessing the success of digital didactic games and guiding their future use in education.

Keywords

digital games, mathematics education, secondary schools, Ukraine, Israel, cluster analysis, student attitudes, gamification, educational technology

1. Introduction

In today's world, digital education is becoming a key success factor [1, 2]. The integration of digital technologies into all aspects of the educational process is undeniably important [3]. Therefore, one of

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the important strategies of digital transformation for general secondary education institutions is the use of innovative technologies and tools to improve the teaching of mathematics [4, 5].

Digital games are used by many teachers in the process of teaching mathematics to students in secondary school. A study by Palha and Jukić Matić [6] showed that the experience of using Digital game-based learning (DGBL) in the teaching process affects teachers' attitudes towards game-based pedagogy. They found that teachers with different experiences with DGBL had different concerns. For example, teachers with extensive experience with DGBL expressed concerns that students did not focus enough on mathematical concepts when using DGBL, about the relevance of the game to the intended learning outcomes, about the need to adapt the game lesson to individual students, and about how to assess the tasks [6]. In contrast, teachers with little experience were concerned about more technical issues, such as the lack of appropriate games [6]. This study confirms the value of using such games in student learning and provides knowledge about the factors that influence its implementation [6].

Understanding fractions is an essential indicator of later success in mathematics, but it remains a difficult topic for many middle school students. Thoma et al. [7] have proven that digital educational games, which complement traditional learning, effectively promote the understanding of fractions. Seventh-grade students (12.3 years old) from schools in Germany participated in the study [7]. Relationships between performance in Semideus' fraction game and specific aspects of fraction comprehension were explored [7]. The results confirm that game performance is significantly correlated with math achievement and whole number arithmetic skills [7]. In addition, significant connections are observed in the understanding of fractions, for example, comparing the size of a fraction and the order of fractions [7]. However, according to scientists, the question remains open to what extent these games can be effective in understanding fractions (part-whole ratio, fraction size, fractional arithmetic) [7].

The problem of math anxiety is relevant for many generations. If this problem is not addressed in school education, it can have long-term consequences and negatively affect careers and life in the future. The study, which was conducted in Taiwan by Ng et al. [8] showed, that children who are afraid of math have worse grades in general, because math anxiety is a serious problem that inhibits learning. Their research showed that even short-term intensive learning to using the digital math games can have a significant impact on reducing math anxiety and improving students' math skills [8]. This makes them a valuable early intervention tool that can help children overcome this problem and succeed in math [8].

Yang et al. [9] suggest using interactive mobile games with a help-seeking mechanism to improve elementary school students' mathematics learning. Their experiment showed that this approach really helps improve learning outcomes and student motivation [9]. They found that games with a help-seeking mechanism were particularly useful for students with low self-esteem [9]. The study highlights the importance of social interaction and collaboration during mobile learning [9]. This approach can be a valuable tool for increasing students' interest and performance in mathematics.

Chan et al. [10] highlights the potential of digital environments to enhance mathematics education in secondary schools. Gaming computer systems help middle school students better understand mathematical equivalence, an important concept for STEM (Science, Technology, Engineering, and Mathematics) disciplines [10, 11, 12, 13, 14]. The digital environments "From Here to There!" was effective for both high and low prior knowledge students [10, 15]. Research by Intergalactic Education LLC shows that using gamification in STEM education programs can motivate more students, particularly minority groups, to study STEM disciplines [16]. Park [16] explored a software platform that used machine learning to analyze educational analytics using the Space World game simulation platform [16]. The study also revealed shortcomings in existing educational technology solutions, such as the display of high-quality graphics and inefficient use of educational data [16].

Israeli researchers Hayak and Avidov-Ungar [17] consider the possibilities of training teachers to use digital games as part of the learning process, including mathematics in elementary school [17]. Worthy of attention are the intelligence of Israeli researchers in the field of studying the opinion of parents, regarding the use of digital games in teaching students mathematics as an alternative to traditional homework [18].

Academic research suggests that digital education can help high school students acquire the math skills they need to succeed in the 21st century, but there are still many unanswered questions.

The *purpose of the research* is to determine and analyze the features of the implementation of digital games in mathematics lessons in secondary schools of Ukraine and Israel using data clustering methods and graphic analysis.

2. Research methods

The research used both quantitative and qualitative methods for data analysis. First of all, it is a method of system analysis, modeling, methods of machine learning, in particular, cluster analysis, a survey method, and graphic analysis, as well as methods of abstraction, formalization, generalization, comparison, and others.

Let us present some of these methods in more detail.

In order to determine the features of the use of the digital math games in the process of teaching mathematics to secondary school students, a questionnaire was used, the questions and answer options of which are presented below:

№1. Enter your gender. (Male / Female).
№2. In which area do you live? (Urban / Rural).
№3. Enter your age. (Input field).
№4. Specify the class in which you study. (Input field).
№5. How often do you play computer (especially phone) games? (Several times a week / I used to play, but now I don't play / Every day / Several times a month / Several times a year).
№6. Have you ever played computer math games? (Yes, I played such games / I didn't play / Friends or acquaintances played).
№7. Have your math teachers used computer math games in their math lessons? (No / I don't remember / Yes).
№8. Would you like computer math games to be used in maths at school? (No / Yes).

After cleaning the data obtained as a result of the questionnaire, preprocessing methods were applied to conduct cluster analysis. The DBSCAN method was used for preliminary estimation of the number of clusters [19]. The Davies-Bouldin Index was also used to estimate the given number of clusters for the K-means method [20]. As previously mentioned, machine learning using the K-means method was used to determine the centroids of the clusters [20, 21].

Data pre-processing and data clustering were carried out in the Google Colab environment [22] using the Python programming language [23].

A study on the definition and analysis of the features of the implementation of the digital math games was conducted in 2023 among students of grades 5-11 of secondary schools in Vinnytsia and Chernivtsi regions. The survey of students was carried out using an online questionnaire.

The survey of Israeli students, which included 77 respondents of different ages and both genders, was carried out using the same online questionnaire as in Ukraine to ensure the comparability of results.

In the presented work, we rely on the general principles that underlie modern digital education, which include elements of constructivism, emphasizing the active role of the student in learning, as well as ideas of gamification, relating to motivation and engagement through game elements. According to the constructivist approach, learners actively construct knowledge through interaction with content, peers, and the learning environment, rather than passively receiving information. Digital games provide an interactive, feedback-rich context that supports such active engagement, enabling students to test hypotheses, apply concepts, and receive immediate feedback on their performance. According to the constructivist approach, learners actively construct knowledge through interaction with content, peers, and the learning environment, rather than passively receiving information. Digital games provide an interactive, feedback-rich context that supports such active engagement, enabling students to test hypotheses, apply concepts, and receive immediate feedback on their performance. Gamification theory, which involves the use of game design elements in non-game contexts, highlights how mechanics such as points, levels, badges, and challenges can foster motivation and sustained engagement. In mathematics education, these elements can help reduce anxiety, maintain attention, and encourage repeated practice, which is essential for mastering complex concepts. Furthermore, the combination of constructivist learning and gamification principles aligns with self-determination theory by supporting students' needs for autonomy, competence, and relatedness. By grounding the design and implementation of digital math games in these theoretical frameworks, educators can ensure that such tools are not only engaging but also pedagogically sound, aligning gameplay with targeted learning outcomes and cognitive development processes.

The selection of Ukraine and Israel as the focus countries for this study was intentional, as it enables the comparison of two educational systems operating in different cultural, socio-economic, and infrastructural contexts. Both countries have faced crisis situations, including state of emergency (including martial law in Ukraine), which have accelerated the search for flexible and innovative teaching methods such as gamification. This comparative perspective allows for the identification of both shared trends and country-specific challenges in the integration of digital didactic games into mathematics education. Although there was no direct connection or interaction between the respondents from the two countries, the same research design, questionnaire, and data analysis methods were applied in both contexts. This approach ensured the comparability of the results while respecting the distinct educational environments of each country.

3. Results

For a comparative study of the use of digital didactic games in mathematics education, Ukraine and Israel were intentionally selected to examine how cultural, socio-economic, and infrastructural factors of different educational systems influence the outcomes of game-based learning. In addition, both countries have experience of crisis situations under state of emergency (including martial law in Ukraine), which forced them to look for new flexible educational solutions, including in the form of gamification. This provides a basis for comparing their effectiveness in conditions of stress or instability.

A survey was conducted to determine the specifics of the implementation of digital games in mathematics lessons in secondary schools in Ukraine. 190 secondary school students took part in the survey. After cleaning the received data, a dataset consisting of 180 samples of respondents' answers was formed for further analysis.

The textual data were transformed into numerical features to implement k-means machine learning to identify patterns that characterize respondents' attitudes toward the use of digital games in secondary school mathematics classes. This was implemented using the code below:

```
data['N1'].replace(['Male', 'Female'],
              [1, 2],
              inplace=True)

data['N2'].replace(['Urban', 'Rural'],
              [1, 2],
              inplace=True)

data['N5'].replace(['Several times a week', 'I used to play, but now I
              don't play', 'Every day', 'Several times a month',
              'Several times a year')],
              [1, 2, 3, 4, 5],
              inplace=True)

data['N6'].replace(['Yes, I played such games', 'I didn't play',
              'Friends or acquaintances played'],
```

```
              [2, 0, 1],
              inplace=True)

data['N7'].replace(['No', 'I don't remember', 'Yes'],
              [0, 1, 2],
              inplace=True)

data['N8'].replace(['Yes, it would be interesting', 'Yes, can be
              tried', 'No, it's inappropriate in math lessons',
              'Yes, I would replace all lessons with computer
              games'],
              [1, 1, 0, 1],
              inplace=True)
```

At the next stage of the research, a preliminary assessment of the number of clusters that can be identified in the set of data instances was carried out.

The preliminary estimate of the number of clusters using the DBSCAN [19] method is 3 clusters. As a result of the Davies-Bouldin Index evaluation [24], a value of 0.4 was obtained, which is a low value that indicates a relatively good degree of similarity of each cluster.

As a result of the application of the K-means data clustering algorithm, the centroids of the clusters were determined, which are presented in table 1. In the cluster analysis, we will consider age and gender components, as well as questions related to the attitude of respondents to the use of digital games, in particular, mathematical games, and questions related to the experience of using such games in mathematics lessons in secondary school in Ukraine. This is question №1, №3 – №8. The values of the centroids were rounded to a whole number.

Table 1
The centroids of the clusters.

Question number	Cluster 1	Cluster 2	Cluster 3
№1	1	2	1
№3	16	11	13
№4	10	5	8
№5	2	2	2
№6	1	1	2
№7	1	1	1
№8	1	1	1

According to the results of the cluster analysis, three groups were obtained, which have the following characteristics (table 1): the first cluster includes mainly girls aged 16 years old, studying in the 10th grade; the centroids of the second cluster are 11-year-old boys studying in the 5th grade; the third cluster is dominated by 13-year-old respondents, girls studying in the 8th grade.

Within each cluster, the indicator of the level of interest of students in digital mathematical games in the process of learning mathematics was evaluated in accordance with the purpose and objectives of the study (table 1). According to the conducted analysis, we observe that there are no significant differences between boys and girls in the amount of time they spend playing digital games. Respondents' answers regarding how often they play computer games turned out to be identical for all clusters – "I used to play, but now I don't". The reasons for such an answer can be different. It can be assumed that in general, interest in digital games may have decreased due to excessive use of them earlier.

The respondents of the first and second clusters are characterized by the fact that they themselves have not played mathematical digital games, but they know about the existence of such games because their friends or acquaintances have played mathematical games (table 1). On the other hand, the respondents of the third cluster played mathematical computer games and are familiar with them.

Also common to all clusters is that students do not remember teachers using digital games in math lessons (table 1). In our opinion, this indicates insufficient awareness of Ukrainian mathematics teachers with the possibilities of using digital educational games in the process of teaching mathematics. And it also shows their doubts that with the help of digital games it is possible to acquire the necessary knowledge, skills, and abilities in mathematics.

It should be noted that all respondents expressed interest in using the digital math games in math lessons (table 1), regardless of gender, age or class of study. When choosing statements that appeal to respondents, they could choose several answer options. In particular, the largest choice fell on the statements "Yes, it would be interesting" and "Yes, can be tried". Thus, we can affirm the relevance and expediency of using digital games in the process of teaching mathematics students.

Analyzing the respondents' answers to the last two questions, we note that there is a discrepancy between the wishes of students regarding the use of digital games in mathematics lessons and the actual state of implementation of digital games as part of the learning process (table 1).

That is, there remains a discrepancy between the enthusiasm of researchers and policy makers in the field of gamification of education, on the one hand, and practical issues of evaluation, selection and implementation of digital games in the educational process, on the other (table 1). The graphical interpretation of the obtained results is presented in the form of a combination of selected clusters for data analysis.

Butterfly charts were built using the Python programming language to analyze the specifics of the use of digital games in secondary school mathematics classes depending on the residence of the respondents in Ukraine (figure 1).

The numbering of the investigated factors characterizing the respondents' answers, which was done to improve the display of figure 1 are presented in table 2.

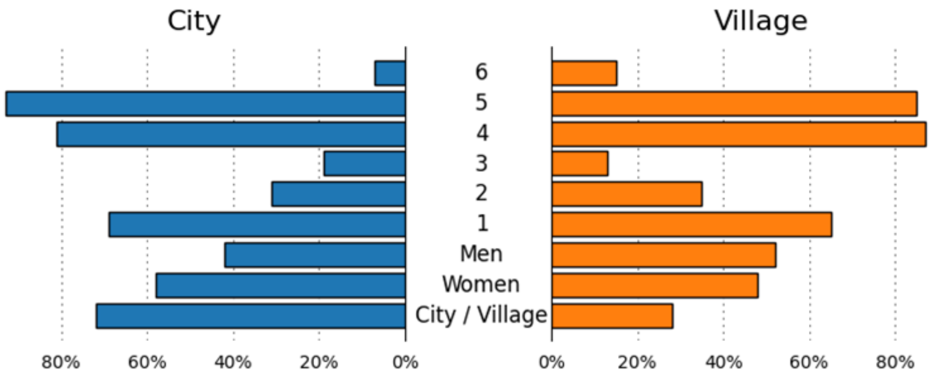

Figure 1: Proportions of students based on the category of residence in Ukraine (City / Village, %).

Table 2
The numbering of the investigated factors characterizing the respondents' answers.

Question number	Respondents' answers
№1	Played digital mathematical games
№2	Didn't play digital mathematical games
№3	Teachers used digital mathematical games
№4	Teachers didn't use digital mathematical games
№5	I wish math teachers would use digital mathematical games
№6	I would prefer that math teachers not use digital mathematical games

Table 3 presents data from the survey results, which represent the percentages of respondents living in rural and urban areas, as well as the survey results in quantitative and percentage relation to the total number of respondents living in urban and rural areas, respectively.

Table 3
Results of the survey of respondents in quantitative and percentage terms who live in urban and rural areas in Ukraine, respectively.

Factor	Number of responses City / Village	Percentage of responses City / Village, (%)
City / Village	134 / 52	72 / 28
Women	78 / 25	58 / 48
Men	56 / 27	42 / 52
№1	93 / 34	69 / 65
№2	41 / 18	31/ 35
№3	25 / 7	19/ 13
№4	109 / 45	81 / 87
№5	125 / 44	93 / 85
№6	9 / 8	7 / 15

Based on the results of the survey, an analysis of students' answers was carried out depending on the type of their place of residence. Thus, 72% of the respondents live in the city, 28% live in the countryside. Since there is an uneven distribution of respondents by type of place of residence, it was decided to analyze respondents' answers in percentage terms (figure 1 and table 2).

So, among the respondents interviewed in urban areas, the share of girls was 58%, while that of boys was 42% (figure 1 and table 2). In rural areas, respectively, the share of girls is 48%, while that of boys was 52% (figure 1 and table 2).

There are certain differences between rural and urban students in the answer to the question "How often do you play digital games?". Respondents living in urban areas play digital games more (69% of respondents answered that they play every day or several times a week) than students living in rural areas (respectively, 65% of respondents play daily or several times a week) (figure 1 and table 2).

It should be noted that the vast majority of respondents from both rural and urban areas expressed interest in using the digital math games in math lessons. When choosing statements that appeal to respondents, they could choose several answer options. In particular, the largest choice fell on the statements "Yes, it would be interesting" and "Yes, can be tried". 93% of urban students gave exactly such answers, while among students in rural areas this indicator is somewhat lower (85% of students believe that it would be interesting for them if the digital math games were used in mathematics lessons) (figure 1 and table 2).

Regarding the use of digital didactic games by teachers in mathematics lessons, it can be stated that teachers in urban areas use such games more often (19% of urban students and 13% of students from rural areas) (figure 1 and table 2).

The analysis from the point of view of the gender characteristics of students regarding the use of digital games in mathematics lessons in secondary schools is also worthy of attention. Butterfly charts were built using the Python programming language (figure 2). According to the previously indicated table, the numbering of the researched factors of the table 4 was used.

Table 4 presents the survey results. The percentage of male and female respondents is given. Also, in quantitative and percentage ratio according to the volume of male and female respondents, the results of the survey are presented.

The table shows that 103 girls and 83 boys took part in the survey, which is 45% and 55% of the total number of respondents, respectively. That is, there were 10% more girls (figure 2 and table 4).

Among the respondents, the share of girls living in cities was 76%, while that of boys was 67% (figure 2 and table 4). In rural areas, respectively, the share of girls is 24%, while that of boys was 33% (figure 2 and table 4).

The percentage of girls and boys who play the digital math games is almost the same, with 67% of girls and 70% of boys (figure 2 and table 4). Similarly, the positive answers of respondents who do not play the digital math games were almost evenly distributed – the share of girls is 33%, while that of

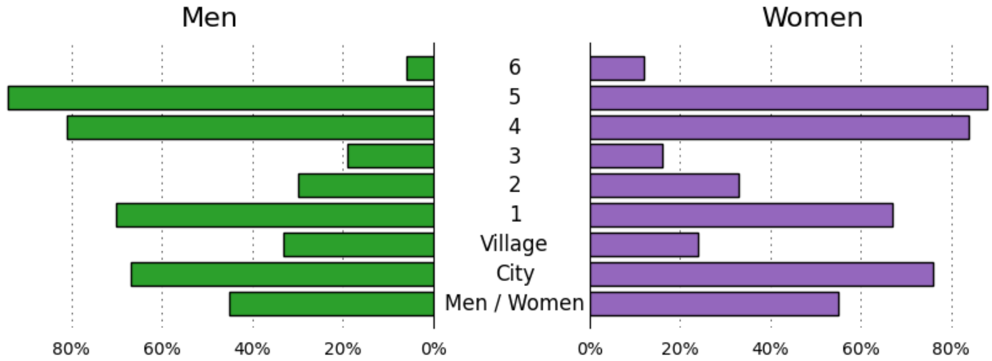

Figure 2: Ratio of students by gender (Male / Female, %), Ukraine.

Table 4
The results of the survey of respondents in quantitative and percentage terms according to gender, Ukraine.

Factor	Number of responses Male / Female	Percentage of responses Male / Female, (%)
Male / Female	83 / 103	45 / 55
City	56 / 78	67 / 76
Village	27 / 25	33 / 24
№1	58 / 69	70 / 67
№2	25 / 34	30 / 33
№3	16 / 16	19 / 16
№4	67 / 87	81 / 84
№5	78 / 103	94 / 88
№6	5 / 12	6 / 12

boys was 30% (figure 2 and table 4). However, there are more students (girls and boys) who play the digital math games.

Respondents' answers regarding whether teachers use digital mathematical games in mathematics lessons were distributed as follows (figure 2 and table 4): they are used – answered by 19% boys and 16% girls; not used – 81% boys and 84% girls . That is, there is a significant preponderance of student responses that teachers do not use the digital math games in math lessons.

It was important to determine whether students wanted their teachers to use mathematical computer games in their mathematics lessons. The vast majority of students answered positively to this question, but 94% boys, compared to 88% girls, expressed a greater desire to use the digital math games in mathematics lessons (figure 2 and table 4). Similarly, fewer boys (6%) gave a negative answer to this question, compared to 12% girls (figure 2 and table 4). That is, more boys showed interest in this type of games than girls.

Let's analyze the results of the survey of respondents in Israel in quantitative and percentage terms according to gender. The survey of Israel schoolchildren was conducted on the same questions as the Ukrainian ones (table 2), in which 77 schoolchildren of different ages participated. Based on the survey data, Butterfly charts were constructed using the Python programming language (figure 3). The numbering of the studied factors in the figure corresponds to the factor number in the table 5.

According to the results obtained (table 4 and table 5), we observe that among Ukrainian schoolchildren there are no significant differences between boys (69%) and girls (65%) in affirmative answers to the question "Have you played digital mathematical games?". In contrast, among Israeli schoolchildren, the number of boys who played the digital math games slightly exceeds the number of girls (63% of boys and 56% of girls).

It is worth noting that among Israeli schoolchildren, the percentage of girls who claim that teachers used digital mathematical games in mathematics lessons is significantly higher (about 20% of boys and

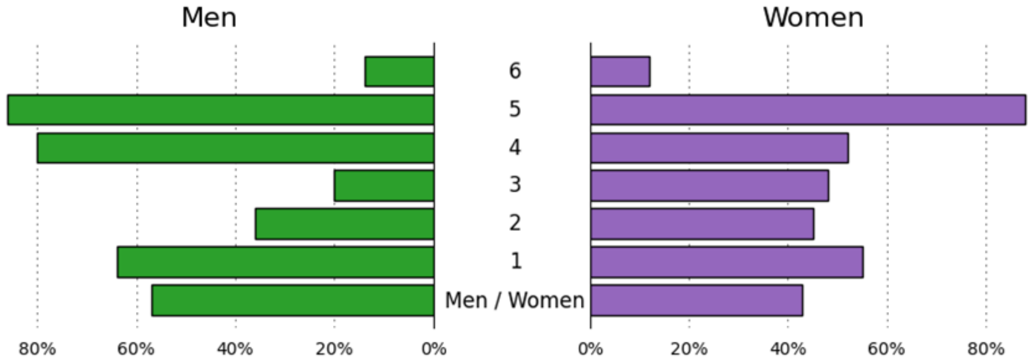

Figure 3: Ratio of students by gender (Male / Female, %), Israel.

Table 5
The results of the survey of respondents in quantitative and percentage terms according to gender, Israel.

Factor	Number of responses Male / Female	Percentage of responses Male / Female, (%)
Male / Female	44 / 33	57 / 43
№1	28 / 18	64 / 55
№2	16 / 15	36 / 45
№3	9 / 6	20 / 48
№4	35 / 17	80 / 52
№5	38 / 29	86 / 88
№6	6 / 4	14 / 12

more than 50% of girls) (table 4). At the same time, among Ukrainian schoolchildren, these data are almost the same by gender, but are significantly lower than among Israeli schoolchildren (less than 20%) (table 5). In our opinion, this indicates that Israeli teachers are more familiar with the possibilities of using digital didactic games in the process of teaching mathematics than Ukrainian teachers and use them in their own activities.

It should be noted that both Israeli and Ukrainian respondents expressed interest in using the digital math games in math lessons. Regardless of gender (more than 80% of both boys and girls in both studies) (table 4 and table 5).

An interesting result is that among Israeli schoolchildren, a slightly larger number of male respondents do not prefer digital games in math lessons (14% of boys and 11% of girls) (table 5). Among Ukrainian schoolchildren, on the contrary, a larger number of girls prefer traditional math lessons, without the use of digital games (7% of boys and 13% of girls) (table 4). And in general, the percentage of Israeli schoolchildren who consider math lessons without digital games to be more appropriate is higher than among Ukrainian schoolchildren.

4. Discussion

The findings of the study confirm several important statements. First, both Ukrainian and Israeli students demonstrated a consistently high interest in the use of digital mathematical games in classroom learning (over 80% in both countries), which indicates the potential of such tools to increase engagement and motivation in mathematics education. Second, despite this interest, the actual use of digital games by mathematics teachers remains relatively low, especially in Ukraine, highlighting a gap between student expectations and current teaching practices. Third, the comparative analysis revealed that Israeli teachers integrate digital didactic games more frequently than their Ukrainian counterparts, possibly due to greater familiarity with such tools and better access to technological resources.

Another important conclusion is that cultural, socio-economic, and infrastructural factors influence the implementation process. Both countries share the experience of adapting their education systems under crisis conditions, which has driven the search for flexible, technology-based teaching solutions. However, differences in teacher training, resource availability, and institutional support shape distinct implementation patterns in each country.

The study also found no direct interaction between respondents from Ukraine and Israel; instead, the research design was based on parallel surveys using identical questionnaires and analysis methods, which allowed for a valid comparison of attitudes and experiences. Based on these results, the authors formulated the stages of integrating digital didactic games into mathematics education, emphasizing planning, technical preparation, testing, evaluation, and continuous improvement. This structured approach, combined with stakeholder feedback, can help bridge the gap between the proven interest of students and the actual application of digital games in mathematics lessons.

We can assume that Israeli schoolchildren's interest in digital games in general may have decreased due to their excessive use earlier, while Ukrainian schoolchildren did not often have the opportunity to play mathematical digital games in class.

As a result of the analysis of the monitoring data of the respondents' responses and our own observations, we determined the stages of implementing digital games in the educational process (figure 4).

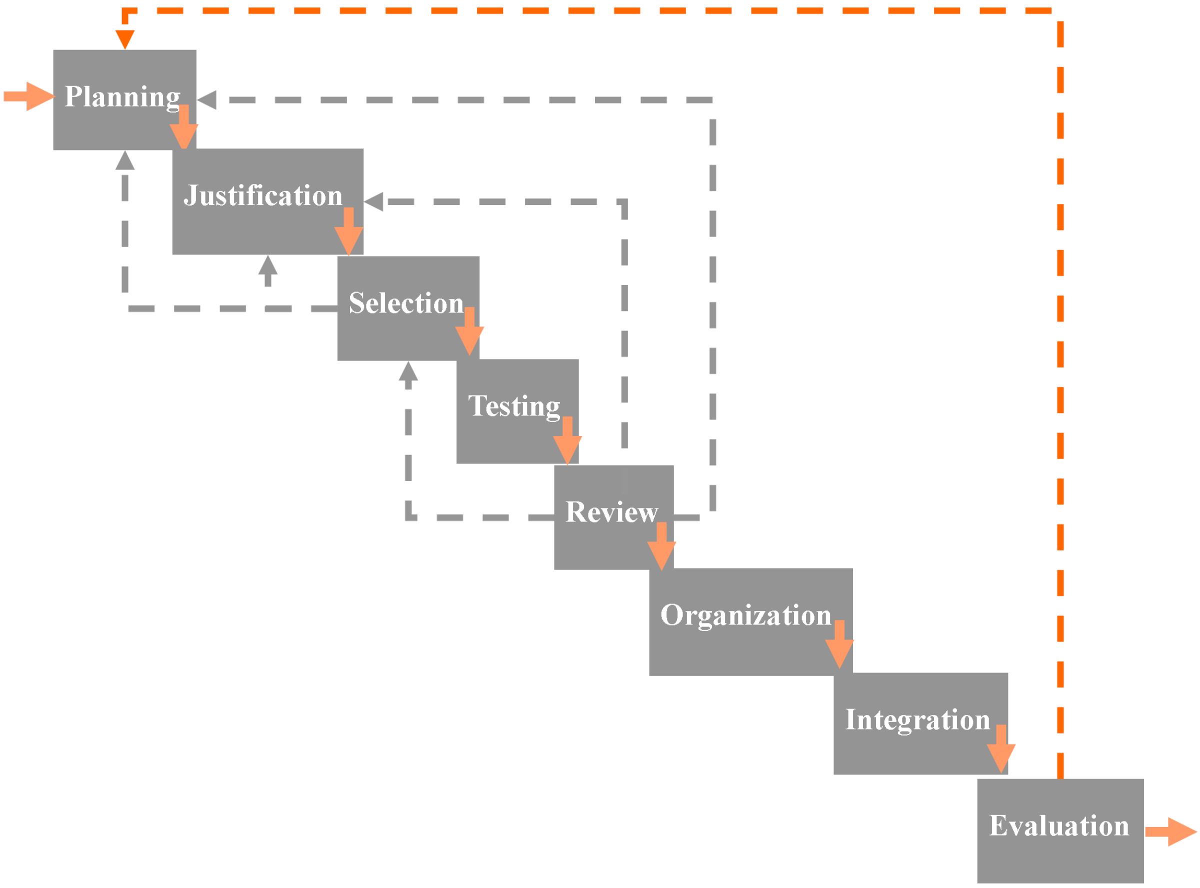

Figure 4: The stages of implementing digital games in the educational process.

At the planning stage, the goals of implementing a digital game are determined. The age of the students is determined. The place of the game as part of the learning process is determined (whether it is an explanation of new material, consolidation of knowledge, reflection, or assessment), the digital platform on which the game is placed or on which the game will be created using the platform's tools for creating such games is determined, and the possibilities of creating a game by a teacher as an independent software product are also considered. The educational goal and learning outcomes are determined. Will the digital didactic game be a separate software product or will it complement an existing game.

At the stage of target justification, specific educational tasks that will be solved in the process of using the game are determined, requirements for the game design in accordance with the age characteristics of the students, the level of their educational achievements. The requirements for the game genre, game interface, and its interactivity are also considered. It is determined whether the game will be team or individual. Language support requirements are taken into account. Important issues of game accessibility are resolved.

At the stage of selection and analysis of the capabilities and technical features of the selected digital didactic game, the game's compliance with the goals and requirements of the previous stages, compatibility with relevant technical and software tools are checked. Game security issues (unwanted content, advertising) are considered. The need for game elements to stimulate students' interest (competitions, achievements, awards) is determined. An important feature of a digital game is its practical orientation, therefore it is also necessary to determine whether there is a need for the game's tasks to be connected with real-life situations.

The testing stage of a digital game is implemented with the participation of a teacher; students, parents, and the administration of a secondary education institution may also be involved in the testing stage of the game.

At the review stage, the results of the digital game testing are summarized, the game's compliance with the requirements is assessed. The need to revise the current requirements for the game is determined, and proposals for possible additions to these requirements are considered.

At the organizational stage, the necessary equipment, software, and access to the game are prepared and configured (Internet, configured devices). Instructions for students on the rules of the game and expected results are also developed. Possibilities of providing support for students during the game, their cooperation if the game is a team game, assistance in solving technical or organizational issues are studied.

At the stage of integration (use) of a digital game into the educational process, the game is directly used and the results of students' academic achievements are monitored, their opinions on the use of the game are monitored. At this stage, it is also important to conduct a survey on the use of this game in the educational process among all stakeholders (teachers, parents and school administration).

Analysis, evaluation and interpretation of the results of the implementation of a digital game, monitoring of students' opinions on the use of the game in the educational process are important for determining the effectiveness of using the game, as well as for further planning of lessons, making a decision on the further use of the corresponding digital game in the educational process. An important aspect of interpreting the results of using a digital game is determining the need for its improvement or replacement with another game, as well as making a decision on whether to continue using the selected game and disseminating effective best practices for its use in the educational process.

5. Conclusion

In summary, it is observed that the results of this study align with broader global trends in education, which increasingly emphasize the integration of digital technologies and game-based learning to enhance student engagement, personalize instruction, and develop 21st-century skills. The high level of interest among students in both Ukraine and Israel mirrors international research showing that interactive, technology-enhanced learning experiences can increase motivation and improve conceptual understanding in mathematics. At the same time, the observed gap between student enthusiasm and teacher implementation reflects a common challenge across many education systems —- the need for targeted professional development, adequate resources, and institutional support for innovative teaching methods.

Currently, in Ukraine, the introduction of digital games into the process of teaching mathematics raises many controversial issues related to various aspects, in particular, the determination of the goals, place and limits of the use of digital games in the educational process, the readiness of mathematics teachers for methodically balanced use of digital games in the process training, to conscious selection of software products. After all, a significant number of teachers are not familiar with the concept of learning based on video games. Even those teachers who use computer games in the process of work face significant difficulties.

There is also an urgent need to develop clear, predictable learning outcomes using digital games that meet national curriculum standards.

That is, there remains a discrepancy between the enthusiasm of researchers and policymakers in the field of gamification of education, on the one hand, and practical issues of evaluation, selection and implementation of digital games in the educational process, on the other.

Based on the analysis of monitoring data and observations in Ukraine and Israel, the stages of integrating digital didactic games into the educational process were identified. These stages include planning the goals and age relevance, justifying the objectives and design requirements, selecting and analyzing technical features, testing the game, reviewing results, preparing necessary resources, and integrating the game into the learning process. Continuous evaluation and feedback from students, teachers, and other stakeholders are essential to determine the effectiveness of the game and decide on its improvement or continued use in the educational system.

The results of the study demonstrate that, despite the high interest of students in the digital math games, there is a significant gap between students' desire to use the digital math games and teachers' actual use of such games, which reflects the broader problem of adapting educational practices to modern digital realities. In future studies, we plan to focus on developing effective methods for introducing digital games into the educational process, investigating the impact of specific types of games on different aspects of mathematics learning, as well as studying factors that hinder or facilitate their wider use by teachers. Additionally, further investigation into teacher training models, school-level implementation strategies, and policy frameworks could provide actionable recommendations for bridging the gap between educational innovation and everyday classroom practice. Collaborative cross-country studies, similar to the present work, would also help identify universal best practices and context-specific adaptations necessary for successful integration of digital didactic games worldwide.

Thus, we consider it appropriate to conduct research related to the study of the place and role of the mathematics teacher in the organization of the educational process with the use of digital games, the interests of mathematics teachers in Ukraine and Israel who plan to use mathematical computer games in order to improve the effectiveness and quality of mathematics education. In addition, this issue remains understudied in Ukraine.

Declaration on Generative AI

The authors have not employed any generative AI tools.

References

[1] T. A. Vakaliuk, V. V. Osadchyi, O. P. Pinchuk, From the digital transformation strategy to the productive integration of technologies in education and training: Report 2023, in: T. A. Vakaliuk, V. V. Osadchyi, O. P. Pinchuk (Eds.), Proceedings of the 2nd Workshop on Digital Transformation of Education (DigiTransfEd 2023) co-located with 18th International Conference on ICT in Education, Research and Industrial Applications (ICTERI 2023), Ivano-Frankivsk, Ukraine, September 18-22, 2023, volume 3553 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2023, pp. 1–8. URL: https://ceur-ws.org/Vol-3553/paper00.pdf.

[2] V. P. Oleksiuk, J. A. Overko, O. M. Spirin, T. A. Vakaliuk, A secondary school's experience of a cloud-based learning environment deployment, in: T. A. Vakaliuk, V. V. Osadchyi, O. P. Pinchuk (Eds.), Proceedings of the 2nd Workshop on Digital Transformation of Education (DigiTransfEd 2023) co-located with 18th International Conference on ICT in Education, Research and Industrial

Applications (ICTERI 2023), Ivano-Frankivsk, Ukraine, September 18-22, 2023, volume 3553 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2023, pp. 93–109. URL: https://ceur-ws.org/Vol-3553/paper7.pdf.

[3] S. Lytvynova, O. Y. Burov, N. Demeshkant, V. Osadchyi, S. Semerikov, 3L-Person: Report, in: S. Lytvynova, O. Y. Burov, N. Demeshkant, V. Osadchyi, S. Semerikov (Eds.), Proceedings of the VI International Workshop on Professional Retraining and Life-Long Learning using ICT: Person-oriented Approach (3L-Person 2021) co-located with 17th International Conference on ICT in Education, Research, and Industrial Applications: Integration, Harmonization, and Knowledge Transfer (ICTERI 2021), Kherson, Ukraine, October 1, 2021, volume 3104 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2021, pp. i–v. URL: https://ceur-ws.org/Vol-3104/paper000.pdf.

[4] O. Klochko, V. Fedorets, S. Tkachenko, O. Maliar, The Use of Digital Technologies for Flipped Learning Implementation, in: O. Sokolov, G. Zholtkevych, V. Yakovyna, Y. Tarasich, V. Kharchenko, V. Kobets, O. Burov, S. Semerikov, H. Kravtsov (Eds.), Proceedings of the 16th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer. Volume II: Workshops, Kharkiv, Ukraine, October 06-10, 2020, volume 2732 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2020, pp. 1233–1248. URL: https://ceur-ws.org/Vol-2732/20201233.pdf.

[5] A. L. Voievoda, O. V. Klochko, R. S. Gurevych, O. L. Konoshevskyi, Comparison of the experience of using digital games in mathematics education in Ukraine and Israel, Journal of Physics: Conference Series 2871 (2024) 012005. doi:10.1088/1742-6596/2871/1/012005.

[6] S. Palha, L. Jukić Matić, Predisposition of In-Service Teachers to Use Game-Based Pedagogy, Electronic Journal of e-Learning 21 (2023) 286–298. doi:10.34190/ejel.21.4.3135.

[7] G. Thoma, J. Bahnmueller, A. Lindstedt, K. Kiili, S. M. Wortha, K. Moeller, M. Ninaus, Different aspects of fraction understanding are associated selectively with performance on a fraction learning game, Progress in Brain Research 276 (2023) 63–91. doi:10.1016/bs.pbr.2023.02.003.

[8] C.-T. Ng, Y.-H. Chen, C.-J. Wu, T.-T. Chang, Evaluation of math anxiety and its remediation through a digital training program in mathematics for first and second graders, Brain and Behavior 12 (2022). doi:10.1002/brb3.2557.

[9] K.-H. Yang, H.-C. Chu, C.-C. Hsieh, F.-R. Kuo, Promoting Students' Math Learning Performance and Engagement: A Help-seeking Mechanism-based Mobile Gaming Approach, Journal of Internet Technology 23 (2022) 1173–1183. doi:10.53106/160792642022112306001.

[10] J. Y.-C. Chan, J.-E. Lee, C. A. Mason, K. Sawrey, E. Ottmar, From Here to There! A Dynamic Algebraic Notation System Improves Understanding of Equivalence in Middle-School Students, Journal of Educational Psychology 114 (2022) 56–71. doi:10.1037/edu0000596.

[11] N. L. Nieto-Márquez, A. Baldominos, A. C. Martínez, M. A. Pérez Nieto, An Exploratory Analysis of the Implementation and Use of an Intelligent Platform for Learning in Primary Education, Applied Sciences 10 (2020) 983. doi:10.3390/app10030983.

[12] M. M. Mintii, STEM education and personnel training: Systematic review, Journal of Physics: Conference Series 2611 (2023) 012025. doi:10.1088/1742-6596/2611/1/012025.

[13] R. P. Kukharchuk, T. A. Vakaliuk, O. V. Zaika, A. V. Riabko, M. G. Medvediev, Implementation of STEM learning technology in the process of calibrating an NTC thermistor and developing an electronic thermometer based on it, in: S. Papadakis (Ed.), Joint Proceedings of the 10th Illia O. Teplytskyi Workshop on Computer Simulation in Education, and Workshop on Cloud-based Smart Technologies for Open Education (CoSinEi and CSTOE 2022) co-located with ACNS Conference on Cloud and Immersive Technologies in Education (CITEd 2022), Kyiv, Ukraine, December 22, 2022, volume 3358 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2022, pp. 39–52. URL: https://ceur-ws.org/Vol-3358/paper25.pdf.

[14] O. S. Pylypenko, T. H. Kramarenko, Structural and functional model of formation of STEM-competencies of students of professional higher education institutions in mathematics teaching, Journal of Physics: Conference Series 2871 (2024) 012004. doi:10.1088/1742-6596/2871/1/012004.

[15] Graspable Math, From Here to There!, 2024. URL: https://graspablemath.com/projects.

[16] J. Park, Using gamification to persuade more women and minorities into STEM, in: Proceedings of the International Astronautical Congress, IAC, International Astronautical Federation, IAF, 2019. URL: https://iafastro.directory/iac/paper/id/49209/summary/.
[17] M. Hayak, O. Avidov-Ungar, Knowledge and planning among teachers integrating digital game-based learning into elementary school classrooms, Technology Pedagogy and Education 32 (2023) 239–255. doi:10.1080/1475939X.2023.2175719.
[18] M. Amzalag, Parent attitudes towards the integration of digital learning games as an alternative to traditional homework, International Journal of Information and Communication Technology Education (IJICTE) 17 (2021) 151–167.
[19] Scikit-learn, DBSCAN, 2025. URL: https://scikit-learn.org/stable/modules/generated/sklearn.cluster.DBSCAN.html#sklearn.cluster.DBSCAN.
[20] Scikit-learn, KMeans, 2025. URL: https://scikit-learn.org/stable/modules/generated/sklearn.cluster.KMeans.html.
[21] O. V. Klochko, V. M. Fedorets, V. I. Klochko, K. A. Klochko, Anthropologically oriented strategies of interaction in the Human-Computer system, Journal of Physics: Conference Series 2611 (2023) 012018. doi:10.1088/1742-6596/2611/1/012018.
[22] Google, Google Collaboratory, 2025. URL: https://colab.google/.
[23] Python Software Foundation, Python, 2025. URL: https://www.python.org/.
[24] Scikit-learn, Davies-Bouldin Score, 2054. URL: https://scikit-learn.org/stable/modules/generated/sklearn.metrics.davies_bouldin_score.html#sklearn.metrics.davies_bouldin_score.