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Didactic Game Based on the Unreal Engine and the Effectiveness of its Implementation in Mathematics Education

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***Abstract* — This study investigates the integration of a didactic game developed using Unreal Engine into elementary school mathematics education, specifically focusing on the teaching of fractions. The research aims to answer the following questions: (1) How do students react to the didactic game? (2) What is the difference between experimental and control group of students? The study involved 46 seventh-grade students from a school in the South Moravian Region of the Czech Republic, randomly divided into two groups: one using the didactic game and one following traditional teaching methods. The research employed both qualitative and quantitative methods, including participatory observation, questionnaires, and didactic tests. The findings reveal that while both groups showed significant improvement in their understanding of fractions, the group using the didactic game demonstrated a more considerable progression, with an average increase in test scores from 38.07% to 71.36%. In contrast, the traditional group improved from 54.17% to 79.68%. Students' reactions to the game were mixed, with some expressing enthusiasm despite technical difficulties, while others were less motivated due to hardware limitations.**

***Keywords* – Educational games, game design, gamification, unreal, fractions teaching, mathematic.**

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1. Introduction

Primary school classrooms often have students with different learning styles, speeds, and attitude. Game-based learning is one way to individualize instruction to the needs of the learner and differentiate instruction [1] while at the same time conceptualizing education in an engaging way and providing a higher degree of immersion in learning.

Games can lead to changes in attitudes, behavior, and skills - just like the teaching process [2]. Game-Based Learning (GBL) is an educational approach that integrates elements from games, such as rules, competition, and interaction, into the learning process. The primary aim is to enhance students' understanding and retention of educational content by incorporating game-related activities. GBL utilizes principles of game design to create an interactive and immersive learning experience [3], [4]. GBL takes various forms including board games, card games, digital games, and interactive simulations or even VR or AR simulations [5]. The success of GBL relies on the thoughtful integration of game elements with educational objectives, ensuring that gameplay aligns with desired learning outcomes.

The evident attraction of games for a significant portion of the learning population is proving to be equally irresistible to instructional designers. People do learn from games. What is needed is a way to design games so that people learn what they need to learn [6].

The origin of the Unreal Engine (UE) dates back to 1998, when the first version was released with the launch of Unreal game [7]. Several versions have been created up to the current Unreal Engine 5. Since 2009, the Unreal Development Kit (UDK) has been released to the public for creating and programming applications based specifically on the Unreal Engine.

Unreal Engine is based on the creation of immersive environments where the developer can interact directly with the main programming languages such as Blue Prints and Visual scripting.

They allow developers to create digital environments based on an interface structured around functions, events and nodes without resorting to code [8].

The engine offers many possibilities for the creation of (not only) didactic games, including overall level design [7], material creation and editing, animation and cinematic scenes, particle effects and sounds, programming in Blueprints or C++ [9], AI and UI creation, Nanite, and Lumen scene lighting [10].

During their studies in primary school, pupils develop key competences, which are represented as a set of knowledge, skills, attitudes, and values based on shared values and ideas in society. The acquisition of these competences takes place during the course of studies and is further developed after graduation. When studying in primary school, it is important to equip individuals with an achievable level of key competences [11], [12].

When integrating the Unreal Engine into educational areas, it is necessary to specify what activities the teacher wants to do in the engine. When working in Unreal Engine, students develop digital competence, which is very important for their professional and personal development. This competence can be developed, among other things, by modelling in 3D, which enables level design, or programming in the visual programming language Blueprints.

Within the Czech school system and curriculum, scene design, specifically 3D modelling, can be included in the design and construction curriculum for the second level of primary education. The teacher can create simple design models with students in Unreal Engine [11], [13]. In the human and the world of work field, level design can also be integrated into the learning area using digital technologies in which students can process graphical information directly in Unreal Engine. At the same time, the UE can be integrated into the art education for the arts and culture learning area [14], as the teacher works with the pupils on 3D computer graphics when working in the UE [15].

Blueprints (BP) programming language can be included in the educational field of informatics under the educational area of the same name specifically, the educational area algorithmization and programming [16]. At the first level, students can experiment with the programming language in the BP editor, building basic programs and their subroutines. With the appropriate Unreal Engine setup from the teacher, students are able to solve almost any algorithmic problem. For example, the teacher can create a checkerboard array in the scene, define custom events (moving a square forward, etc.) start and finish areas, and obstacles.

He or she will then ask the students to perform the teacher's task directly in the BP editor. The use of the Blueprint editor in this learning strand can also be applied at the second level, where pupils will begin to learn, for example, loops, variables and branching of the program.

2. Didactic Game for Practicing Mathematical Fractions in Unreal Engine

This research is focused on the application to mathematics lessons, in the form of a didactic game created in Unreal Engine, for the teaching of fractions in year 7 of elementary school (children aged about 12 years). The goal was to create a didactic game taking the whole fractions curriculum, to implement the research investigation was to implement addition and subtraction of fractions. The form of the game can be seen in Figure 1. It is an Unreal Engine project with a third person template, i.e. a third person game. In the game, students walk around the map and complete problems on signboards or city tasks incorporating fractions.

Figure 1. Game world

An important part of the game is the UE quest system. After setting up the quest system, it was necessary to do retargeting for the player's character (fitting the skeleton of the default character to the skeleton of the model character from the city), thus completely changing its appearance while keeping the controls and animations from the original character. Objects that can be taken from repositories have also been added to the game. Many widgets were created during the creation of the game. Programming concepts from Blueprints were also applied in the widgets, as they contain the Blueprint editor. Many variables were set in the widgets to represent the values displayed in them. When math problems are displayed in widgets, 1 of 32 problems is generated for each level of the game. It was therefore necessary to specify the problems for each level of the themes and an algorithm to verify their correctness. There are currently 512 mathematical problems in the game and more will be added. In addition to programming the concepts associated with the message boards, it was necessary to create a structure for completing tasks that was not available in the quest system.

The time intensity of the implemented parts of the work with fractions is as follows: addition of fractions - 2 hours, addition of mixed numbers - 3 hours, subtraction of fractions - 2 hours, subtraction of mixed numbers - 3 hours. The examples for addition and subtraction are always divided into 8 levels. The individual levels in a given part of the curriculum cannot be skipped, so the player must first complete the previous levels. This lockout has been added to the game to avoid possible issues if students start a different level that they do not yet know. In order to complete a given level in the game, the player must calculate a few examples on that topic in the message board, of which there are seven around the map. Each of them contains different levels of the given parts of the curriculum to complete. A teleport has been set up to help move between the message boards more quickly. The currently available levels are shown in a bright colour. Those that are not available cannot be started and the player must first complete the previous levels. After starting a level, a different widget will pop up for the player to practice that level.

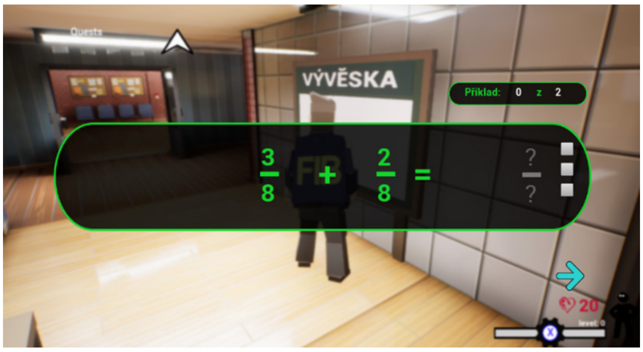

Figure 2. Example of addition of fraction

Once the player enters the result, he or she clicks on the blue arrow to continue counting. The examples are chosen randomly from 32 different possible problems for each level of the game (Figure 2).

Before completing a quest in the city, it is required to complete at least one level for that part of the curriculum. Fraction addition tasks are marked with a green exclamation mark, while fraction subtraction tasks are marked in purple. The colour of the problems corresponds to the colour distribution in the bulletin boards. After accepting a quest, the player is shown the name of the quest received and what the player is to do under the quests sign. After completing the quest, the player returns to and interacts with the quest giver, who assigns a reward to the player.

When integrating a game into mathematics education, it is first necessary to determine how the didactic game will be integrated. The teacher can choose from the following options.

- A didactic game will be used to discuss the new curriculum.
- The didactic game will be used to reinforce the learning.
- The didactic game will be used to practise the material at home.

3. Methodology

The research problem is oriented descriptively and in a causal way. In the research, the plan was to find out whether students achieve better results when implementing the didactic game than students without it. At the same time, however, students' reactions when playing the didactic game were investigated. Two research objectives were set:

1. Evaluate students' reactions to the didactic game.
2. Compare the results of two classes.

Objective 1 is chosen to fulfill the descriptive orientation of the research problem; therefore, no hypotheses were formulated. On the other hand, objective 2 ranks more towards the causal orientation of the research problem. In this objective, the hypotheses were set as follows:

[A] Before the research is conducted, the results of the class with the didactic game will be statistically equal to the results of the class without the didactic game.

[B] There will be statistically significant differences in the results of the class with the didactic game before and after the research.

[C] There will be statistically significant differences in the results of the class without didactic play before and after the research.

[D] After the research is conducted, the results of the class with didactic game involvement will be statistically different from the results of the class without didactic game involvement.

Qualitative participatory observation was chosen to identify objective 1. The qualitative research method was chosen in order to capture students' specific reactions to the didactic game and to reflect their emotions while playing the didactic game. In order to increase the validity of the findings from the observation to meet this research objective, a quantitative questionnaire with scaled items and open-ended questions was also used.

These were 5 scaled statements with a possible rating of 1 star-disagree to 5 stars-agree. The statements were as follows:

- I understood what to do in the game.
- I would play the game again.
- The game controls were too complicated.
- The problems in the game were difficult.
- The game helped me to understand the material.

The last open-ended question asked students for their opinion: what would they change about the game?

The objective 2 was identified through quantitative analysis of the tests from the students. Testing was conducted in two phases, with pupils completing tests in each phase, which were then evaluated. Students were first given entrance tests to assess their knowledge before the research was conducted. They then completed exit tests that assessed students' knowledge after the research was conducted. The corrected and evaluated didactic tests were used to compile the data for this research method. The entry test was set at 15 minutes and the maximum score range was set at 12 points. For the exit test, 25 minutes were allotted with the possibility of extending the time according to the students' needs. The maximum score was set at 24 points.

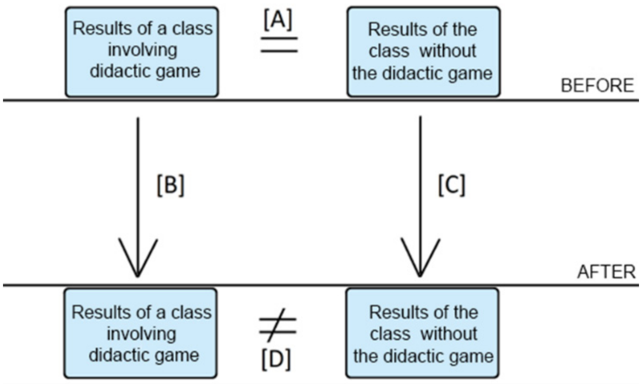

Figure 3. Diagram of the hypotheses dependencies

When comparing two classes based on their results and then determining the more advantageous teaching method, it is imperative that the classes being studied have balanced results when entering the research. Since statistical research methods will be applied to the comparison of results, it is necessary to make a random selection, which was achieved by randomly grouping the classes. Firstly, it was verified that the classes were at the same level before entering the research using hypothesis [A]. This hypothesis was evaluated using the Mann-Whitney U-test, which was applied to the entry tests.

For the classes, it was further examined whether there is progression of students in the subject matter during instruction. This progression was examined by hypothesis [B] and [C] for each class. By confirming hypothesis [B], it was investigated whether progression occurred during the research in the classroom with a didactic game. The same approach was applied to hypothesis [C], which focuses on the classroom without a didactic game. The evaluation of hypotheses [B] and [C] was carried out with the Wilcoxon test. After the research was conducted, it was examined whether the classes have different results. By confirming hypothesis [D], it was investigated whether the classes are at a different level, this hypothesis was evaluated using the Mann-Whitney U-test. A diagram of the hypotheses will be presented to better understand the dependencies between the hypotheses (Figure 3).

The research population for the empirical investigation were two seventh grade classes in a school in the South Moravian Region of the Czech Republic. A total of 46 pupils participated in the research. The classes for the research were chosen randomly without prior information about them, and the assignment of which class would be with and without the didactic game was also random. The research took place during mathematics lessons, where one of the classes was always moved to the computer room to interact with the didactic game.

4. Teaching Implementation and Research Progression

First, the students completed an entry test (entry knowledge analysis), which was designed to test what knowledge the students had on the topic. Then the main part of the empirical investigation took place during two lessons. Observation was practiced in the didactic game class and a questionnaire was filled in. After the investigation, the students completed exit tests (analysis of results), these tests were to verify what knowledge the students have after the empirical investigation.

The actual implementation of the didactic game was done in the following way. After explaining the controls of the game, it was necessary to explain to the students what was expected of them in the game. This always involved counting examples on the explained problem. Students were provided with a workbook which they could use if necessary. In the first lesson, students completed 4 levels of fraction addition in a series of steps. After completing all four levels on addition of fractions, students had to start completing tasks in the city on the same topic. Students were given tasks called "Collecting envelopes" and "Stock up at the donut shop".

The objective of the mentioned tasks is to calculate five examples for adding fractions and interact with the environment while doing so. As the lesson came to a close the teacher had the students fill out a feedback form from the lesson, which they then turned in anonymously. In the second lesson, the pupils were asked to go to a noticeboard with examples of subtraction and complete the first 3 levels, thus practising the lesson. From the lesson on subtraction of fractions, students were given the problems entitled 'Collecting envelopes' and 'Helping in the shop'. During the second lesson, there was an exit test to complete and 25 minutes were allocated for this.

5. Evaluation of Research Objective [I] – Participant Observation and Questionnaires

During the participant observation, there were large differences in the students' ability to control the game, which made it difficult for the children to progress in the game, but this was a minority of the students.

In addition to the control problems, the game was choppy and this reduced students' motivation to play the game and therefore some probably did not like it. This was due to the weaker hardware of the computers in the school classroom. On the other hand, most of the class was interested in the game and somehow got used to the chopping. Students progressed quickly in completing the bulletin board levels, although some needed help with calculations. A smaller proportion of the class progressed to completing tasks in the city in class, which some individuals were enthusiastic about.

The questionnaire was submitted by 22 students. Responses to questions rated 1 star (disagreement) to 5 stars (agreement) were organized and evaluated in the following table. For each question, the frequency of stars was evaluated (denoted n_i where i represents the number of stars, so $i \in \{1; 2; 3; 4; 5\}$) applies. The table also shows the arithmetic mean ($\bar{x}$); the variance (σ^2) and standard deviation (σ) of the given values. All position and variability characteristics are rounded to two decimal places.

Table 1. Responses to the questions

	n_1	n_2	n_3	n_4	n_5	$\bar{x}$	σ^2	σ
I understood what to do in the game.	0	1	4	4	13	4,32	0,85	0,92
I would play the game again.	3	4	2	6	6	3,38	2,05	1,43
The controls of the game were too complicated.	3	3	3	7	6	3,45	1,88	1,37
The problems in the game were difficult.	2	7	9	2	2	2,77	1,08	1,04
The game helped me with my understanding of the curriculum.	2	5	6	4	4	3,14	1,55	1,25

The evaluation of open-ended question 6 yielded quite a lot of consistency in students' answers. Pupils here wrote in most cases that the game was slowing down, which was caused by the computers at school. Below is a summary of the responses to this question along with the frequency of responses.

- Game stutters (18 times)
- Option to adjust graphics or edit graphics (4 times)
- Game controls (3 times)
- School Wi-Fi (2 times)

The data obtained from this research method shows that students were most often bothered by game chopping on school computers. This negative influence is likely to have affected students' judgement for questions two (chopping would make some students not play the game anymore) and three (chopping affected game control). The average of the data shows that the class attitude towards re-playability is neutral or rather positive. The class has similar results for question 3, which indicates that the control is rather difficult/neutral between categories.

The greatest agreement amongst the students was found for question 1, which shows that the majority understood what to do in the game. Students in the class indicated that they were not sure if they understood the material. This response was predictable due to the fact that the material was only covered in the first lesson; related to this is the students' opinion of the difficulty of the examples.

6. Evaluation of Research Objective [II] – Didactic Tests

The entry and exit tests were completed by 7th grade students in the second stage of primary education in the Czech Republic (children around 12-13 years of age). Classes were anonymized.

The class without the use of the didactic game as class X, the class with the use of the didactic game as class Y. The table on the next page shows the results of the tests of class X and class Y. The ordinal digit represents the identification number of the student in the class. The participant observation shows that the class with the didactic game was only possible to complete certain levels. To evaluate this research method, only the examples that were discussed in both classes were evaluated in the tests. Thus, the analysis of the tests showed that the entry test did not include points for examples i) j) k) l) and the exit test did not include exercises 3 and 4. The maximum score range changed from 12 points to 8 points for the entry test and from 24 points to 15 points for the exit test.

Table 2. Entry and exit tests results

Order number	Entry test result (Class X)	Exit test result (Class X)	Entry test result (Class Y)	Exit test result (Class Y)
1	5	9,5	8	13,5
2	7	12,5	7,5	14,5
3	6	15	0	5
4	6,5	15	1	9,5
5	4	14,5	3	14,5
6	4,5	14	2	8
7	7	13,5	7	10,5
8	7,5	12,5	0	9,5
9	6	13	1	8,5
10	2	15	0	10,5
11	7	13	1	14
12	4,5	10,5	3	13
13	4	12	0	6,5
14	5,5	13,5	7,5	13
15	1	11	1	9,5
16	0	0	8	12,5
17	2	11,5	7,5	11,5
18	6	13,5	6	15
19	2,5	10	0	7,5
20	2	10,5	2	8
21	1	11	0	6
22	–	–	1,5	15

The previous data from the didactic tests were evaluated in the following table, which shows the mean test score ($\bar{x}$), the variance of the test score (σ^2) and the standard deviation (σ).

These position and variability characteristics will be rounded to two decimal places and compared to each other in the evaluation of this research method.

Table 3. Mean test score, variance, and standard deviation

	$\bar{x}$	σ^2	σ
Entry test class X	4,33	5,10	2,26
Entry test class Y	3,05	9,54	3,09
Exit test class X	11,95	9,88	3,14
Exit test class Y	10,70	9,33	3,06

The data in Table 3 shows that class X performed on average better than class Y in the entry test. This difference may be due to various factors and it is not the purpose of this research to investigate these factors.

Elimination of some of the effects could be achieved by randomly selecting research individuals rather than randomly selecting research classes, which is difficult to achieve when conducting this particular research.

The didactic test data evaluated shows that class X performs better than class Y before and after the research. In class Y there is a greater progression in class performance as the average percentage of success (rounded to two decimal places) increased from 38.07% to 71.36% compared to class X, which increased from 54.17% to 79.68%.

7. Mann-Whitney U Tests

Mann-Whitney U tests were used for hypotheses [A] and [D]. Mann and Whitney tests showed that for groups larger than 20 members, the tested U criterion has a roughly normal distribution. The evaluation of the null hypothesis was tested according to the normalized normal random variable u. A modified formula was used to calculate this variable, because the data of didactic tests indicated that the numbers of points in the tests are repeated and the evaluation of the hypotheses could then be biased by this effect [17]. To confirm or refute the null hypothesis, a significance level of 0.05 will be chosen and it will be a two-sided test [18]. The null hypotheses A_0 and D_0 were chosen in agreement with hypotheses A and D, and the alternative hypotheses (A_A a D_A) represent its refutation.

[A_0] Before the research is conducted, the results of the class with didactic game involvement will be statistically equal to the results of the class without didactic game involvement.

[D_0] After the research, the results of the class with the didactic game will be statistically different from the results of the class without the didactic game.

Table 4. Ranked data for Mann Whitney U test

Class X - before		Class Y - before		Class X - after		Class Y - after	
Number of points	Ranking	Number of points	Ranking	Number of points	Ranking	Number of points	Ranking
0	4	0	4	0	1	5	2
1	10,5	0	4	9,5	10,5	6	3
1	10,5	0	4	10	13	6,5	4
2	17	0	4	10,5	15,5	7,5	5
2	17	0	4	10,5	15,5	8	6,5
2	17	0	4	11	18,5	8	6,5
2,5	20	1	10,5	11	18,5	8,5	8
4	23,5	1	10,5	11,5	20,5	9,5	10,5
4	23,5	1	10,5	12	22	9,5	10,5
4,5	25,5	1	10,5	12,5	24	9,5	10,5
4,5	25,5	1,5	14	12,5	24	10,5	15,5
5	27	2	17	13	27,5	10,5	15,5
5,5	28	2	17	13	27,5	11,5	20,5
6	30,5	3	21,5	13,5	31,5	12,5	24
6	30,5	3	21,5	13,5	31,5	13	27,5
6	30,5	6	30,5	13,5	31,5	13	27,5
6,5	33	7	35,5	14	34,5	13,5	31,5
7	35,5	7,5	39,5	14,5	37	14	34,5
7	35,5	7,5	39,5	15	41	14,5	37
7	35,5	7,5	39,5	15	41	14,5	37
7,5	39,5	8	42,5	15	41	15	41
–	–	8	42,5	–	–	15	41

To calculate the criterion U the formula (1) and also the formula (2) are used, the latter of which is determined as U = min (U_1;U_2).

$$U_1 = n_1 \cdot n_2 + \frac{n_1 \cdot (n_1+1)}{2} - R_1 \quad (1)$$

$$U_2 = n_1 \cdot n_2 + \frac{n_2 \cdot (n_2+1)}{2} - R_2 \quad (2)$$

The entry test results were distinguished from the exit test results by adding a comma to the given formulas.

The data show that the frequency of class X of the entry test (n_1) and the frequency of the class of the exit test (n'_1) are both equal to 21. For class Y, it is also true that the frequency of the entry test (n_2) and the frequency of the exit test (n'_2) are both equal to 22. The previous table shows that the sum of the rank of class X in the entry test (R_1) is equal to 519.5 and in the exit test (R'_1) is 527. The sum of the rank of class Y in the entry test (R_2) is 426,5 and in the exit test (R'_2) is 419.

After substituting in the formulas to calculate U_1; U_2; U'_1 and U'_2 the value of criterion U (173,5) for the entry tests and the value of criterion U′ (166) for the exit tests were obtained.

The *U* criterion value is needed to calculate the absolute value of the normalized normal variable $|u|$. This is calculated according to the corrected formula (3) [17].

$$|u| = \frac{U - \frac{n_1 \cdot n_2}{2}}{\sqrt{\frac{n_1 \cdot n_2}{n \cdot (n-1)} \cdot \frac{n^3 - n}{12} - \sum \frac{r^3 - r}{12}}} \quad (3)$$

The calculated value of the $|u|$ and $|u'|$ criteria for the entry and exit tests will be compared with the critical value $u_{0,05} = 1{,}96$ for the two-sided test. The normalized normal random variable can be read, for example, in [18]. The absolute value of the normalized normal random variable $|u|$ for entry tests and $|u'|$ for exit tests rounded to two decimal places (4) (5).

$$|u| = \frac{173{,}5 - \frac{21 \cdot 22}{2}}{\sqrt{\frac{21 \cdot 22}{43 \cdot (43-1)} \cdot \frac{43^3 - 43}{12} - 64{,}1\overline{6}}} \quad (4)$$

$$|u'| = \frac{166 - \frac{21 \cdot 22}{2}}{\sqrt{\frac{21 \cdot 22}{43 \cdot (43-1)} \cdot \frac{43^3 - 43}{12} - 36}} \quad (5)$$

From the formulas were obtained the rounded values u=1,42 and u′=1,6.

Since these values are less than 1.96 for a significance level of 0.05, the null hypothesis A_0 was accepted and the null hypothesis D_0 was rejected which implies that the alternative hypothesis D_A was accepted. Thus, based on these hypotheses, the hypothesis [A] was accepted and the hypothesis [D] was rejected.

8. Wilcoxon Tests

For the evaluation of hypotheses [B] and [C], the Wilcoxon test was chosen, which is used in repeated measures of the same subjects [17]. Different scoring scales appear in the tests, therefore the percentage of success of individual students in the given tests will be considered. The null hypotheses B_0 and C_0 were defined as the opposites of hypotheses B and C, respectively:

[B_0] There will be no statistically significant differences in the results of the didactic game class before and after the research.

[C_0] There will be no statistically significant differences in the results of the class without the didactic game before and after the research.

The alternative hypotheses B_A and C_A are then hypotheses B and C themselves.

Table 5. Class X

Order number	Percentage of student success		*d*	Ranking	+	-
	Entry test	Exit test				
1	62,5	$63,\overline{3}$	$0,8\overline{3}$	1,5	1,5	–
2	87,5	$83,\overline{3}$	$-4,1\overline{6}$	4	–	4
3	75	100	25	11	11	–
4	81,25	100	18,75	9	9	–
5	50	$96,\overline{6}$	$46,\overline{6}$	16	16	–
6	56,25	$93,\overline{3}$	$37,08\overline{3}$	14	14	–
7	87,5	90	2,5	3	3	–
8	93,75	$83,\overline{3}$	$-10,41\overline{6}$	5	–	5
9	75	$86,\overline{6}$	$11,\overline{6}$	6	6	–
10	25	100	75	20	20	–
11	87,5	$86,\overline{6}$	$-0,8\overline{3}$	1,5	–	1,5
12	56,25	70	13,75	7	7	–
13	50	80	30	12	12	–
14	68,75	90	21,25	10	10	–
15	12,5	$73,\overline{3}$	$60,8\overline{3}$	18,5	18,5	–
16	0	0	0	–	–	–
17	25	$76,\overline{6}$	$51,\overline{6}$	17	17	–
18	75	90	15	8	8	–
19	31,25	$66,\overline{6}$	$35,41\overline{6}$	13	13	–
20	25	70	45	15	15	–
21	12,5	$73,\overline{3}$	$60,8\overline{3}$	18,5	18,5	–

The sum of the data in the + and - columns shows that the Wilcoxon test criterion (S) is equal to 10.5. At the 0.05 level of signifikance $S_{0,05}(20) = 52$ [19].

Therefore, null hypothesis B_0 was rejected and the alternative hypothesis B_A, was accepted because 10,5 < 52. Since the alternative hypothesis coincides with hypothesis [B] it can therefore also be accepted.

Table 6. Class Y

Order number	Percentage of student success		d	Ranking	+	-
	Entry test	Exit test				
1	100	90	-10	3	–	3
2	93,75	$96,\overline{6}$	$2,91\overline{6}$	1	1	–
3	0	$33,\overline{3}$	$33,\overline{3}$	10	10	–
4	12,5	$63,\overline{3}$	$50,8\overline{3}$	16,5	16,5	–
5	37,5	$96,\overline{6}$	$59,1\overline{6}$	18	18	–
6	25	$53,\overline{3}$	$28,\overline{3}$	8,5	8,5	–
7	87,5	70	$-17,5$	6	–	6
8	0	$63,\overline{3}$	$63,\overline{3}$	19	19	–
9	12,5	$56,\overline{6}$	$44,1\overline{6}$	13	13	–
10	0	70	70	20	20	–
11	12,5	$93,\overline{3}$	$80,8\overline{3}$	21	21	–
12	37,5	$86,\overline{6}$	$49,1\overline{6}$	14	14	–
13	0	$43,\overline{3}$	$43,\overline{3}$	12	12	–
14	93,75	$86,\overline{6}$	$-7,08\overline{3}$	2	–	2
15	12,5	$63,\overline{3}$	$50,8\overline{3}$	16,5	16,5	–
16	100	$83,\overline{3}$	$-16,\overline{6}$	4	–	4
17	93,75	$76,\overline{6}$	$-17,08\overline{3}$	5	–	5
18	75	100	25	7	7	–
19	0	50	50	15	15	–
20	25	$53,\overline{3}$	$28,\overline{3}$	8,5	8,5	–
21	0	40	40	11	11	–
22	18,75	100	81,25	22	22	–

When calculating the sum of the data in the + and - columns, it is found that the value of the tested criterion of the Wilcoxon test (S´) is 20. At the significance level of 0.05 for 22 elements, the value of $S_{0,05}(22) = 65$ [19]. Since 20 < 65, the null hypothesis C_0 is rejected and the alternative hypothesis C_A. Hypothesis [C] is therefore confirmed.

9. Evaluation and Discussion

Hypothesis [A] and [D] were evaluated using Mann-Whitney U-test for the selected significance level of 0.05. By confirming hypothesis [A], it was found that the results of the classes before the research were statistically the same. After the research was conducted, the results of the classes were again statistically the same (found by rejecting hypothesis [D]). Hypotheses [B] and [C] were evaluated using the Wilcoxon test again for a significance level of 0.05. By confirming hypothesis [B], it was found that the results of the class involving didactic game use were statistically different before and after the research.

The same was true for the results of the class without the involvement of didactic game (confirmation of hypothesis [C]). A summary of the rejected and confirmed hypotheses can be seen in the following diagram (Fig. 4).

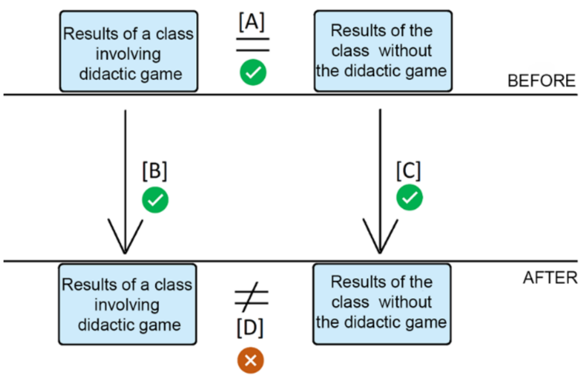

Figure 4. Diagram of the hypotheses confirmation

It was established that the class without the didactic game before the research achieved on average better scores than the class with the didactic game. Both classes must have been familiar with the curriculum in some way, as some individuals achieved success rates of over 90% in the parts of the entry didactic test studied. However, when hypothesis [A] was evaluated, it was found that the difference in the results of the entry tests between the classes studied was not statistically significant. The didactic test data evaluated shows that the class with the didactic game involvement shows a more radical progression in the average percentage of students' achievement than the class without the didactic game involvement. By evaluating hypotheses [B] and [C], it was found that there was a statistically significant progress in students' achievement in the classrooms during the research. The results of the outcome tests showed that the class without didactic game, after the implementation of the research, achieved better average results than it did before the research. By evaluating hypothesis [D], it was found that the results of the classes after the implementation of the research are not statistically different.

The class without the implementation of the didactic game had on average better results than the class with the didactic game. When comparing the classes before the research was conducted, it was found that the class without didactic game had better average results. For an ideal research process, it would be useful to achieve two identical copies of the classes in order to qualitatively assess which class has the more appropriate teaching method. It is also possible to conduct a global survey in the Czech Republic to obtain more comparable quantitative data.

The empirical research was descriptive and exploratory in orientation, so the reader can try to investigate students' reactions to didactic games in several schools, possible research questions are: is there a positive attitude towards didactic games in schools? Do pupils globally have better results when implementing the game? Is there an optimal way to implement the game in the classroom? Will pupils perform better when implementing the game than pupils without implementing the game in the classroom?

10. Conclusion

This research aimed to evaluate the impact of a didactic game based on the Unreal Engine in teaching mathematical fractions to seventh-grade students. The study employed a mixed-methods approach, combining qualitative observations, questionnaires, and quantitative didactic tests to assess students' learning outcomes and engagement.

The findings indicate that while the didactic game led to a notable progression in the average performance of the class using the game, the overall effectiveness of the game-based learning approach did not surpass traditional teaching methods significantly. Both the class with the didactic game and the class without it showed statistically significant improvements in test scores, suggesting that both approaches effectively enhanced students' understanding of fractions. However, the lack of a statistically significant difference in the final test results between the two classes indicates that the game-based method did not provide a distinct advantage over traditional methods.

Challenges such as technical difficulties, particularly the choppiness of the game due to inadequate hardware, negatively impacted students' motivation and overall experience. This suggests that for game-based learning to be more effective, the technical execution must meet certain standards to ensure a smooth and engaging learning experience.

In conclusion, while the didactic game demonstrated potential in enhancing students' engagement and learning in mathematics, its effectiveness is contingent on the quality of implementation. Further research with better technical support and a more refined game design could provide clearer insights into the benefits of game-based learning in educational settings.

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