Acta Didactica Napocensia

Volume 18, Number 1, 2025 - DOI: 10.24193/adn.18.1.5

TEACHING MATHEMATICS WITH NON-DIGITAL TOOLS: A CASE STUDY WITH ELEMENTARY SCHOOL STUDENTS USING POLY-UNIVERSE GAME

Edith DEBRENTI, Hajnal Annamária BELLA

Abstract: Teachers in kindergarten, primary, and secondary schools use hands-on manipulatives to help students grasp concepts in areas such as numbers, operations, geometry, algebra, measurement, data analysis, and probability. These manipulatives and interactive games are essential for fostering mathematical understanding, enabling students to build, reinforce, and connect different representations of mathematical ideas. Skillfully incorporating manipulatives in lessons has significant potential to enhance students' learning in mathematics. A key objective of our research was to introduce the Poly-Universe game family to students in grades I to VI, mathematically gifted high school students, and primary teachers. By familiarizing participants with the game's basic shapes, sizes, colors, and various applications, we aimed to investigate students' problem-solving and problem-posing abilities through action research—beginning with methodological examples and progressing to games and ideas they developed themselves. Our observations revealed that students who engaged in problem-solving activities showed a positive shift in their attitude toward learning mathematics. We also found that the Poly-Universe kit could be effectively integrated into personal development, language, math, and art classes, making it a versatile tool adaptable to nearly any classroom. The play set encouraged creative thinking through hands-on activities and challenging scenarios, making learning enjoyable and confidence-boosting for students of all ages. From a teacher's perspective, we believe these tools are invaluable, as they allow every student to create and experience moments of success.

Key words: Primary education, mathematics education, educational games, gamification, game-based learning, non-digital gamification, Poly-Universe game family, STEAM education, interdisciplinarity

1. Introduction

Zeng et al. (2020, 187.) consider that "*educational games are games designed and developed for specific educational and teaching objectives, which stimulate learners' motivation and participation by combining education and gameplay and helps to achieve the educational goal by allowing earners to achieve their stated learning goals in a pleasant experience*".

Integrating educational games into the teaching and learning process has demonstrated encouraging outcomes at all levels of education. Games can effectively teach various mathematical concepts (Dienes, 1967). The use of tangible objects is crucial for grasping new ideas (Oláhné Téglási, 2023). Manipulatives and games are vital tools for improving mathematical comprehension, enabling students to create, reinforce, and connect different representations of mathematical ideas. High-quality games offer learners flexibility and independence, making them particularly advantageous. These games are crafted to align with cognitive and mathematical frameworks, facilitating the integration of diverse types and levels of knowledge (Debrenti, 2024a).

Received October 2024.

Cite as: Debrenti, E. & Bella, H. A. (2025). Teaching mathematics with non-digital tools: a case study with elementary school students using Poly-Universe game, *Acta Didactica Napocensia*, 18(1), 46-58, https://doi.org/10.24193/adn.18.1.5

Game-based learning (GBL) involves utilizing games for educational purposes to enhance users' knowledge and experiences. A key benefit of these educational games is their emphasis on fostering essential life skills in children, such as problem-solving and critical thinking. GBL creates opportunities for experiential learning, allowing learners to acquire knowledge and experience through interactive and engaging gameplay. The study of non-digital mathematical games has become a growing area of research on a global scale. In previous research Debrenti (2024b) found that students demonstrated better solutions with non-digital games, than with their digital counterparts.

Talan et al. (2020) conducted a meta-analysis of 180 effect size comparisons derived from 154 empirical studies examining the impact of both digital and non-digital games on academic achievement from 2004 to 2019. The overall sample size across these studies was 12,800 participants. The findings indicate that educational games positively influence academic achievement, the higher effect size of non-digital games suggests that they may be more effective for learning and development, potentially due to greater opportunities for peer interaction, a broader range of activities, more flexible design and content, and various platforms to play.

Guan et al. (2022) in their systematic review studied 35 experimental studies that substantially integrated gaming elements in primary school lessons. Their major findings include that there is a lack of empirical studies on GBL research in primary education. Besides, minority children or children of special needs have not received equal attention in thereviewed studies. *"The majority of games were digital ones, which means that children needed to participate in activities via some kind of screen-based technologies*" (Guan et al., 2022, 14.).

Öztop (2022) conducted a study investigating the influence of incorporating games into primary school mathematics education on learning outcomes. By comparing effect sizes across different game types, the findings indicate that the effect size for digital games is small (0.436), whereas the effect size for non-digital games is large (1.032). These results suggest that non-digital games have a significantly greater impact than digital games on learning outcomes in primary school mathematics education.

Many researchers observed a contrast between the following things: in the real-life primary teachers prefer using of non-digital games with students, but in the literature the predominant research focus is on digital games, particularly in mathematics (Russo, 2024c; Hainey et al., 2016; Hussein, 2022).

Russo et al. (2021, 2024a, 2024b) discovered that over three-quarters of Australian primary school teachers utilize games multiple times a week to enhance mathematics instruction. These teachers showed a strong preference for non-digital games in the classroom over digital alternatives. In practice, primary school educators predominantly employ non-digital mathematical games, such as board, dice, and card games, to facilitate math learning. Almost all primary teachers reported playing mathematical games in their classrooms at least once a week, considering these games highly effective for developing the four proficiencies emphasized in the Mathematics Curriculum: fluency, understanding, problem-solving, and reasoning. According to Russo et al. (2021), when asked about their preferred mathematical activities for the classroom, only 1% of teachers selected a digital game or app, and just 4% chose a game that included any form of digital technology, such as calculators, random number generators, or interactive charts. Other studies support these findings, showing that primary educators are three to five times more likely to use non-digital math games than digital ones during lessons. Additionally, they are 10 to 14 times more likely to express a preference for non-digital games over digital alternatives. This strong preference for non-digital games in primary mathematics instruction is notable, especially given the widespread use of digital technology in many aspects of life, including education (Russo et al., 2024a).

Russo et al.'s (2024b) analysis revealed a number of reasons that explained why primary teachers preferred non-digital games, most commonly pedagogical reasons such as: they better facilitate collaboration and communication; they provide opportunities for learners to use manipulatives; and they can be easily adapted and differentiated for different groups of learners, the perception that when students played non-digital games it was easier to observe their understanding.

Sousa et al. (2023, 149.) found that *"the activities involving the Poly-Universe, a tool to teach mathematics are motivating, as the students' interest and motivation during this study was notorious. The use of objects with such attractive characteristics, that appeal to visualisation, permitted the exploration of different figures and its characteristics and the comprehension of some geometric* *concepts. As well as positive interaction and collaboration of the students, the discussion and the development of their geometric reasoning were remarkable*".

Schmidthaler et al. (2013) previously argued that Poly-Universe supports meeting curriculum requirements and predefined teaching and learning objectives in an engaging, playful manner. Moreover, the game not only fosters computational thinking (CT) in secondary education but also enhances enjoyment and peer collaboration in biology and physical education lessons.

Similarly, Matos et al. (2023) found that Poly-Universe materials served as a valuable teaching resource for solving assigned tasks, particularly in exploring geometric concepts such as perimeter and triangle similarity. Their hands-on manipulation facilitated the visualization of these concepts and actively engaged students in the learning process.

A key objective of our research was to introduce the Poly-Universe game family to students in grades I to VI, to mathematically gifted secondary school students, and to primary teachers. By familiarizing participants with the game's basic shapes, sizes, colors, and various applications, we aimed to investigate students' problem-solving and problem-posing abilities through action research—beginning with methodological examples and progressing to games and ideas they developed themselves.

2. Theoretical background

The process of learning how to teach occurs in various ways. Teachers can employ a wide range of resources, from hands-on materials to technological tools, to make lessons more engaging and spark students' interest in the content, thereby helping them to build knowledge.

Manipulatives are objects designed to represent abstract mathematical ideas concretely and explicitly (Moyer, 2001). These materials act as physical representations of abstract concepts, facilitating reflective thinking by linking learners to external realities (Van de Walle, Karp, and Bay-Williams, 2009). Teachers use manipulatives to help students grasp abstract symbols and concepts in mathematical language. In classrooms, manipulatives are used to introduce abstract mathematical ideas and enhance younger students' existing knowledge (Hunt, Nipper, and Nash, 2011; McNeil and Jarvin, 2007). Using objects that are relevant to students' own experiences can aid in developing their problem-solving and problem-posing abilities. Engaging with real-world objects turns students into active participants, improving their skills as they work towards solutions. According to Kelly (2006), teachers can assess students' learning by evaluating their use of instructional materials in problem-solving. Research indicates that students who use manipulatives achieve better results in problem solving, as these concrete experiences actively engage them in the learning process (Suydam, 1986; Clements, 1999). By working with tangible objects, students can visualize mathematical concepts (DeGeorge and Santoro, 2004).

Rosli, Goldsby, and Capraro (2015) examined the use of manipulatives in school mathematics, discussing their role and benefits. Their study emphasized how manipulatives support problem-solving and problem-posing while also exploring strategies to optimize their use. According to Rosli et al. (2015), manipulatives help students build connections between mathematical concepts and improve their problem-solving skills, even when applied to real-world scenarios. Furthermore, research by Quane (2024) indicates that young children enjoy using manipulatives, which positively influences their perception of mathematics and their sense of competence.

In the case of manipulative materials, geometric shapes, with their exploration, develop the sense of sight and touch, while, at the same time, the capacity for thought and abstraction is improved by the recognition of correlations to find points of connections. In this learning process, the following functions are mobilized: vision, touch, detection, perception, attention, memory, discovery, discovery of the part and the whole, imagination, creativity, and problem solving (Anđić et al., 2022).

The curriculum encompasses the development of skills such as orientation in the plane, spatial visualization, spatial reasoning, and the ability to recognize figures in various contexts (Debrenti, 2016). Orientation in the plane involves practicing the four primary directions: up, down, right, and left. Mastering these directions is fundamental for learning reading, writing, and mathematics. Concepts such as columns and rows are introduced and practiced through tabular organization. Points on a square grid can be identified using two pieces of information, characterized by naming the rows and columns, similar to how it is done on a chessboard (Herendiné, 2013).

Bakan (2018) argued that games allow for more information to be conveyed to students than in traditional classroom settings, and the knowledge gained through games tends to be more lasting. This is because students are more engaged in the lessons and actively participate in the learning process.

In a literature review of previous studies, Hafeez (2022) found that game-based learning (GBL) is a highly effective strategy across multiple disciplines and educational settings. This approach greatly enhances learner engagement in the learning process. A comparison of game-based and traditional learning methods, based on 26 published articles, revealed that GBL is more effective than traditional teaching strategies.

Chang et al. (2017) conducted a study comparing the flow experiences and types of cognitive load—intrinsic, relevant, and extraneous—between game-based learning (GBL) and non-game-based learning groups. The study involved 50 students in the experimental (GBL) group and 53 in the control group. The findings showed that students in the GBL group experienced greater flow than those in the non-game-based group. They also demonstrated a stronger ability to concentrate on and control their own learning. Aligned with constructivist theory, the use of games significantly enhances problem-solving skills and fosters active learning. Games create an engaging environment where learners can work independently and benefit from hands-on, experiential learning.

Recently, teachers and educators have started exploring non-digital gamification (NDG) as an alternative approach in schools. This method incorporates elements of fun, exploration, and active engagement to enhance learning through features like challenges, interest, self-expression, exposure, immediate feedback, clear objectives, player control, collaboration, competition, rewards, and low-risk environments (Ke et al., 2016). The NDG approach utilizes physical game models like cards, dice, board games, or teacher-created innovations. Through games, students solve problems or tasks, allowing them the freedom to plan strategies, explore, and discover solutions independently (Park & Lee, 2017). This approach also enables teachers to conduct formative assessments by observing students' actions, decisions, and interactions during the game.

Non-digital gamification (NDG) offers several advantages over digital games in educational settings. One major benefit is its affordability, as NDG eliminates the need for technological setup or compatibility concerns, allowing for seamless integration into lesson plans. Additionally, NDG ensures inclusive accessibility, enabling all students to participate regardless of their access to digital devices, making it particularly beneficial for schools with diverse technological resources. The hands-on nature of NDG enhances engagement and comprehension by providing a multisensory learning experience through physical interaction with game components- an aspect often limited in digital environments. Moreover, NDG fosters face-to-face interaction, encouraging communication, collaboration, and cooperative problem-solving, which may be less emphasized in digital games that primarily involve individual screen time. Beyond engagement, NDG often simulates real-world scenarios, helping students establish tangible connections between theoretical concepts and practical applications. By minimizing screen reliance, NDG also addresses concerns related to excessive screen time, contributing to a healthier learning environment. Overall, its adaptability, inclusivity, tactile learning benefits, and emphasis on social interaction make NDG a valuable and effective educational tool (Setambah et al., 2024).

3. Methodology

3. 1. Research questions

In our research we tried to find the answer to the following questions: are non-digital games suitable for developing math skills? Do they facilitate or hinder development compared to traditional practice?

RQ1. Are elementary students today interested in non-digital tools?

RQ2. How do they feel when they play? Does the elementary student experience any success or difficulties when using the game?

RQ3. What transversal skills do children develop when they participate in such activities?

RQ4. Do pupils' interests in a new non-digital game vary between different age/sex groups?

RQ5. Does the use of a non-digital, constructivist toolkit engages the majority of learners in the activity and helps them to better master, practice and understand the material?

RQ6. Does the use of non-digital, constructivist games develop (reinforce) a positive attitude towards mathematics learning in pupils during the activity?

3. 2. The Poly-Universe Toolkit

The didactic tool Poly-Universe is an *"educational game, aims to create a new visual system for teaching mathematics. It is a didactic tool with multiple scientifically proven benefits. It is a training system for aesthetic and mathematical skills based on the symmetry of scale change, inherent to its geometric shapes. It is made up of manipulable materials, with combinations of primary colours, in different ways, which allows infinite combinations and aims to develop a new methodology for mathematics education"* (Santos et al., 2023, 235.).

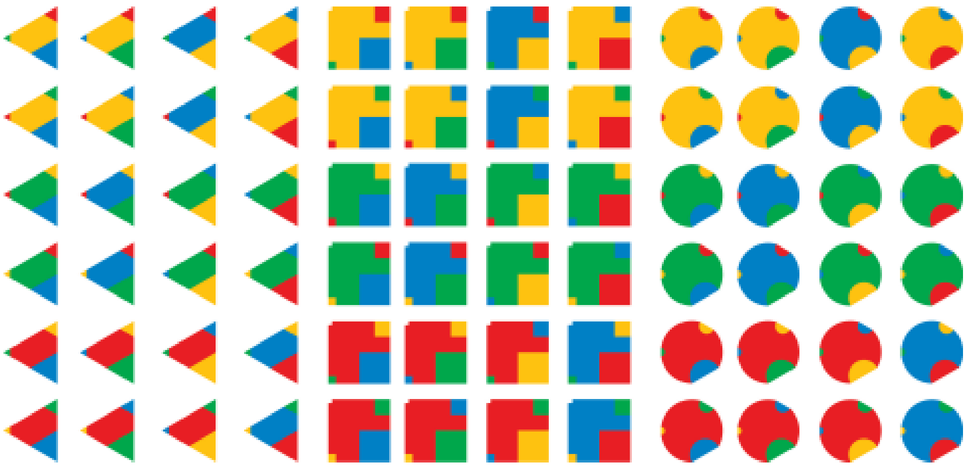

Figure 1. *The Elements of the Poly-Universe Game Family.*

The inventor of the game, János Saxon Szász, is a visual artist who tried to combine art with mathematics through the simplicity of the game family. This game family is not only aimed at students who excel in maths, but its form and simple colours also try to find a key to all students who excel in art. By linking art to the formal world, the learner uses both hemispheres of the brain to think, to form relationships.

Figure 2. *The Poly-Universe game has three different basic shapes.*

The Poly-Universe game family is based on three basic shapes: circle, triangle, and square. Each of these basic shape sets consists of 24 toy elements.

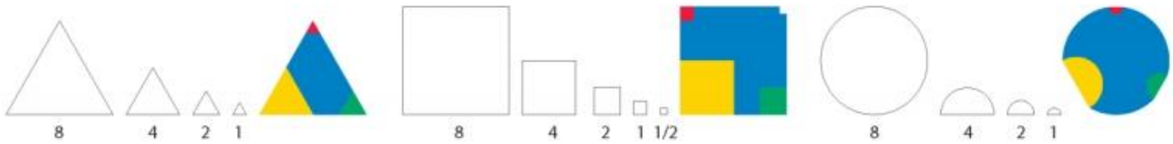

Figure 3. *The Poly-Universe game -one shape, four different sizes.*

The colours of the game family are red, green, yellow, and blue. All four colours can be found on a single piece, making it a very eye-catching toy. The base colour is the colour of the middle range of the specific toy.

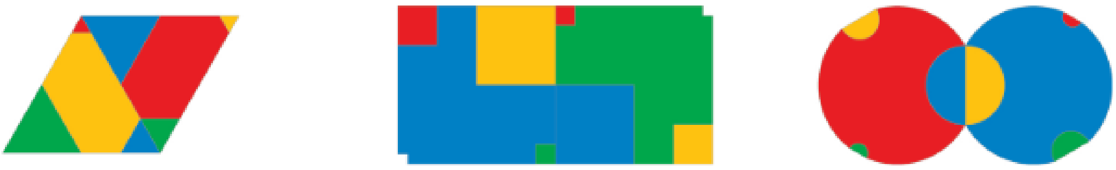

Figure 4. *Linking the game elements*

A game piece can be divided into four parts in terms of size: the basic piece part (A), the large part (N), the medium part (K), the small part (P) and, in the case of a square, the hole part (L).

Figure 5. *The meeting of the elements at the top*

Over the past decade, thousands of teachers and students aged 6 to 18 have tested this game in hundreds of institutions and events across Europe, including school workshops, conferences, "art & mathematics" festivals, and museums.

Figure 6. *Offset contact of the elements of the Poly-Universe*

3. 3. Research participants

Our research took place in three different age groups, in Primary School No.2 in Pécska, Arad County (Romania). The first age group was the first-grade students of the school, 8 children in total, 7 boys and 1 girl. The second age group was the fourth-grade students of the school, 10 children in total, 4 boys and 6 girls. The third age group was the school's sixth-grade students, with a total of 12 children, 6 boys and 6 girls. The total group that participated in the experiment consisted of 30 students, including 13 girls (43.33%) and 17 boys (56.66%).

Table 1 presents the sample distribution by group and sex:

Table 1. *Sample Distribution by Grades and Sex*

Sample	Girls		Boys		Total
	Number	***Percentage***	***Number***	***Percentage***	***Number***
First grade	1	12.5%	7	87.5%	8
Fourth grade	6	60%	4	40%	10
Sixth grade	6	50%	6	50%	12
Total	**13**	**43.33%**	**17**	**56.66%**	**30(100%)**

3. 4. Intervention

Our main research method was action research, in the school year 2022/2023. This was combined with observation, questionnaires, and inquiry-based learning. Action research is a qualitative research method and summarises the reflections of the activities carried out, is a planned sequence of human activities that can be evaluated in relation to the goal set. In our case, the activity was the presentation and application of the Poly-Universe kit itself, the activities with the game family. The participants have been selected: three different age groups (pupils from 1st to 6th grade).

The research spanned eight weeks and consisted of four structured activities. Students were assigned to random groups, and the game rules were explained either to the entire class or to smaller groups. The selected games were age-appropriate and engaging for the students, with rules designed to be clear and easy to understand. Data and information on practical application was collected, and new game ideas were written down and collected.

The first lesson was the only one similar for each three grades: we introduced the game family, they examined it, touched it, looked at it and then started to play with it. The activity took place in a classroom, as part of the afternoon session, between 13 and 14.30 PM, in the first week of October. We met with the age groups on different days. The questions we asked during the lesson were: Here is this game, what can you do with it? What else can be done with it?

After the first introductory lesson, the students filled in the IMI (Intrinsic Motivation Inventory) questionnaire. (We filled in the questionnaire also with the first graders and took notes on what they said.)

The second lesson (second week of October) was different for each group and included:

For 1st grade students: The purpose of the lesson was to create living things and objects that they are interested in and that surround them. They then count how many elements their creation contains. If they want, they can draw it. Meanwhile, they can use all the toy families, even mixing and matching the elements.

For 4th grade students: The aim of the lesson was to invent a game in which they can use the elements of the game family, even as an addition to another game. All three forms could be used.

For 6th grade students: Form 3 groups according to the basic shapes and then make diagrams from the exercises in the PUSE method book. Count the number of elements in the diagrams they have drawn.

The third lesson (second week of November) included:

For 1st grade students: Express their feelings using the basic triangle shapes of the game family. We associated the emotions with the colours and then they had to consider the colours of the parts of the element: basic element, large element, medium element and small element. They then had to create a picture that reflected their emotions and depicted something that characterised them. After the creations, we discussed the emotions and the image they had created.

For 4th grade students: Concrete exercises. What shapes did you use? Discussion, talking, experimenting.

For 6th grade students: Creating closed shapes from images as in the methodology. The groups could choose from a selection of images. The difficulties of the shapes were discussed.

The fourth lesson (second week of December) included:

For 1st grade students: They were asked to play with the play set as they liked, using all the shapes and play elements, even in groups. Filling in an IMI questionnaire.

For 4th grade students: Incorporating their own games, inventing new games. Presentation of the games. Using all forms and game elements. Completing the IMI questionnaire.

For 6th grade students: Find a game from the Poly-Universe game family that you know or don't know. We have offered the following: dice, Twister spinner, Boom ball, hourglass. Fill in IMI questionnaire.

After the activities with the games, we thought that the set of games would be used as a didactic tool in the different subjects. We incorporated it into the options given by the weekly theme and the daily theme. We tried it first in the teaching of mathematics. Within the subject, we used the elements as a tool for calculating and exercising addition and subtraction with first grade students. The second one we tried was drawing, also with the first graders. The students drew around the shapes, created a picture of them, and then coloured them in their favourite colours using watercolours. The next two subjects in which the play set was used were mother tongue and personal development, also with first grade students.

We also played with the games in the style of classic board games, adapting, incorporating, adding to and renovating them.

We also tested the participants' attitudes after learning and using the Poly-Universe game and compared them with the attitudes when the tool was presented. The results were recorded, conclusions of the development were drawn.

On 22 March 2023 was a meeting of the primary teachers in Arad County, this took place at the Primary School No. 2 in Pécska. The theme of this meeting was the development of creativity. During the presentations we also introduced the Poly-Universe toolkit, and after the presentation the teachers themselves could try out the game, we held a workshop for them. Afterwards we asked them to fill in the IMI test. The questionnaire was completed by 21 active primary teachers. When evaluating the questionnaire, we wanted to know the teachers' views on what transversal skills they thought children could develop if they participated in similar activities with the Poly-Universe toolkit.

On 13 May 2023, the national stage of the Csillagszerző Mathematics Competition was held in Oradea, at the Lorántffy Zsuzsanna Reformed Secondary School. One of the free activities after the competition was to get acquainted with the Poly-Universe game toolkit. The aim of our action research was to introduce the game family to the students who are gifted in mathematics, to observe their attitude towards the toolkit, and after a short introduction to it, we also wanted to find out what subjects they could imagine using it as a didactic tool.

We just said, "Here's this Poly Universe game, what are you going to do with it?" To help, we said: you can put them together at the tops, sides, even slide them. At first, they didn't ask for any help, they started to puzzle out different geometric shapes on their own from elements they chose. Once they had one, we just asked if they could do a different shape, or if they could do the same geometric shape in a different colour combination.

Those who wanted to create something beautiful as a group asked for help to see if there was a more interesting shape they could do together. The rosettes in the methodology book (Anđić et al., 2022) appealed to everyone. They put them up together, where they decided the tasks within the group, they assigned them to each other. The rosettes required all the triangles and all the circle elements.

Another group, at the urging of a 5th grade's boy, created a shape based on the rosette, but with all the elements of a square added. There, they had a great sense of achievement as together they created a completely new shape.

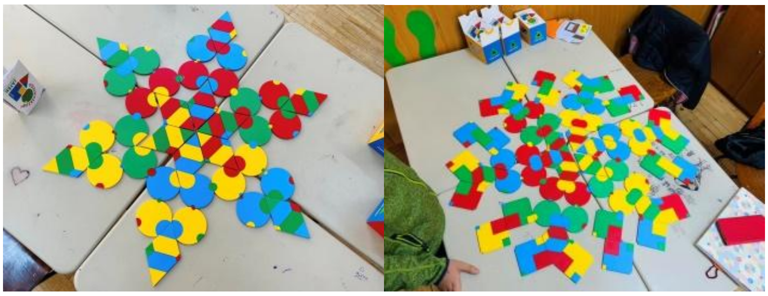

Figure 7. *A classic rosette based on the book and a new one created by students.*

4. Results and Discussion

During the intervention with the students, it was observed that the toolkit encourages group work, roles are formed almost automatically within the group, and the students encourage each other to move forward while working. The creation of something new and the freedom from making mistakes fostered their creativity.

To evaluate the activities, we used an IMI (Intrinsic Motivation Inventory) questionnaire before and after the intervention. We have used the following subscales of the original test: Interest/Enjoyment, Perceived competence, Effort/Importance, Pressure/Tension, Perceived choice/autonomy, Value/Usefulness.

We used the IMI test for primary teachers too, and in addition to the intrinsic motivation, we have also added additional statements about the specific course to improve it:

1. It was easy to start using this game in mathematics.
2. This game can be used in different disciplines.
3. This game can be used in different educational contexts, e.g. formal, non-formal and informal.
4. This game can be used to implement games in education.
5. This game can be used to learn how to design and implement interdisciplinary activities.
6. We believe that in the future I will be able to carry out activities like those carried out in this workshop.

Additionally, to enhance the workshop, we posed four questions to participants, allowing them to share their thoughts on the Poly-Universe course in a few sentences:

- What did you enjoy most during the workshop?
- What challenges did you face?
- What was the most valuable takeaway from the workshop, and why is it useful to you?
- What suggestions do you have for improving the workshop? (Oláhné Téglási, 2023)

When analysing the responses to the IMI test, in case of primary teachers, the following results were obtained. The optional transversal skills mentioned by primary teachers were understanding, teamwork, creativity/creative thinking, problem solving, critical thinking, sharing/cooperation, concentration/attention, autonomy, innovation/innovation, decision making, responsibility.

According to the primary school teachers surveyed, the following transversal skills are mentioned (in descending order): creativity/creative thinking (21 teachers, 100%), group work (19 teachers, 90.47%), problem solving skills (18 teachers, 85.71%), concentration (18 teachers, 85.71%), cooperation (14 teachers, 66.66%), autonomy (13 teachers, 61.90%), innovation (10 teachers, 47.61%), understanding

(8 teachers, 38.09%), decision making (8 teachers, 38.09%), responsibility (7 teachers, 33.33%), critical thinking (6 teachers, 28.57%).

Table 2 presents the results of the IMI test in case of elementary students:

Table 2. *Quantitative results of the IMI questionnaire*

Students	Pretest mean (%)	Posttest mean (%)	STDEV (pre, post)	t-test (p)
First grade	84.50	85.63	2,56 /2.82	3.81(0.006)
Fourth grade	86.40	88.20	2.06/2.89	3.37(0.008)
Sixth grade	86.50	88.16	2.39/2.55	3.70(0.003)

From the results, we can conclude that such practice-based, tool-based activities are very useful for learners, and the averages of students in different grades improved during the activities.

The Poly-Universe toolkit is a creative, innovative game based on geometric elements, so students who are gifted in maths, will see the connections between shapes much sooner than students who are not so good at maths. The introductory lessons are almost negligible for children who are gifted in maths, and who have figured out a solution on their own, without the help of the method book. Understanding has been replaced by a desire to create.

Our research did not focus specifically on the different ways of thinking of boys and girls. In our research age group, which was very small, the girls preferred the familiar patterns and algorithms, while the boys' desire to create was influenced by novelty, by creating something new, discovering and creating something that was not yet there.

With the play set presented, we wanted to demonstrate that the Poly-Universe toolkit can be used in almost any classroom. Playing with game is an experience, and it is through experiential pedagogy that we can best develop the competences of our students. As learners learn, collaborate, analyse, think, and problem-solve through play, participation in the experience itself prepares the learner for life. In summary, the teacher's main task is to make learning an experience. Play is the best way to motivate learners, and if the learner is motivated, he or she will learn and learn well.

5. Conclusion

As a consequence of our observations during the experiment, we can formulate our answers to the research questions: Are elementary students today interested in non-digital tools? During the intervention with the students, it was observed that the elementary students today are interested in non-digital tools, they like this toolkit very much and the activities with it (RQ1).

How do they feel when they play? Does the elementary student experience any success or difficulties when using the game? During the intervention with the students, it was observed that the toolkit encourages group work, the elementary students work together very well, the students encourage each other, they were very creative, collaborative, and initiative (RQ2).

What transversal skills do children develop when they participate in such activities? According to the primary school teachers surveyed, the following transversal skills are mentioned (in descending order): creativity/creative thinking, group work, problem solving skills, concentration, cooperation, autonomy, innovation, understanding, decision making, responsibility, critical thinking (RQ3).

Do pupils' interests in a new non-digital game vary between different age/sex groups? During the intervention, we observed that primary school students were interested in non-digital tools, both boys and girls, with no difference in terms of gender or in terms of age groups, all students were engaged in every activity in this experiment, students enjoyed the game and the toolkit (RQ4).

It was confirmed that the use of a non-digital, constructivist toolkit engages the majority of learners in the activity and helps them to better master, practice and understand the material (RQ5).

It was confirmed also that the using of the non-digital, constructive games, a positive attitude towards mathematics learning is developed (reinforced) in the pupils during the activities (RQ6).

The non-digital manipulative games, as didactic games, are an effective method for developing mathematical skills. The action research has been successful; further conducted studies should be considered to see whether Poly-Universe would be an effective tool for older learners and to investigate whether age is a significant factor, given that first and second graders require more play due to their age characteristics, which may not be the case for older children. Only 30 children participated in this experiment; it would be worthwhile to work with a larger group to further test the effectiveness and applicability of the method in the classroom.

Our further plans include, how to develop the use of the tool, the experiences, the good practices in an optional subject, to share with colleagues, to develop a teaching material, even to publish it.

We would like to present the conclusions and suggestions to other professional audiences.

Our observations revealed that students who engaged in playing with the toolkit, during the problem-solving activities showed a positive shift in their attitude toward learning mathematics. We also found that the Poly-Universe kit could be effectively integrated into personal development, language, math, and art classes, making it a versatile tool adaptable to nearly any classroom. The play set encouraged creative thinking through hands-on activities and challenging scenarios, making learning enjoyable and confidence-boosting for students of all ages. From a teacher's perspective, we believe these tools are invaluable, as they allow every student to create and experience moments of success. So have a Poly-Universe in every classroom!

Acknowledgements

The authors thanks to János Saxon-Szász for graciously permitting the use of his figures and images, which have made this paper more informative and visually representative.

References

Anđić, B., Bordás, A., Fenyvesi, K., Hoffmann, M., Szász Saxon, J., & Téglási, I. (Eds.). (2022). *PUNTE methodological study: Poly-Universe in teacher training education – Handbook for pre-service and in-service teachers and students* (pp. 12-15). Líceum Press-Eszterházy Károly Catholic University, Eger. http://www.punte.eu/punte-study/

Bakan, U., and Bakan, U. (2018). Game-based learning studies in education journals: A systematic review of recent trends. *Actualidades Pedagógicas*, *1*(72), 119-145.

Chang, C.-C., Liang, C., Chou, P.-N., and Lin, G.-Y. (2017). Is game-based learning better in flow experience and various types of the cognitive load than nongame-based learning? Perspective from multimedia and media richness. *Computers in Human Behavior,* 71, 218–227.

Clements, D. H. (1999). "Concrete" Manipulatives, Concrete Ideas. *Contemporary Issues in Early Childhood*, *1*(1), 45.

Debrenti, E. (2016). Some Components of Geometric Knowledge of Future Elementary School Teachers. *Acta Didactica Napocensia, 9*(3), 11-20. ISSN 2065-1430.

Debrenti, E. (2024a). Game-based learning experiences in primary mathematics education. *Frontiers in Education,* 9:1331312, ISSN 2504 284X. https://doi.org/10.3389/feduc.2024.1331312

Debrenti, E. (2024b). Using digital game-based learning in mathematics education: A case study with teacher training students. *International Journal for Technology in Mathematics Education, 31*(3), 153-162. https://doi.org/10.1564/tme_v31.3.06

De George, B., and Santoro, M. A. (2004). Manipulatives: A Hands-On Approach to Math. *Principal*, 84, 2.

Dienes, Z. P. (1967). *Building up mathematics*. London: Hutchinson Educational Ltd.

Guan, X., Sun, C., Hwang, G., Xue, K., Wang, Z. (2022). Applying game-based learning in primary education: a systematic review of journal publications from 2010 to 2020, *Interactive Learning Environments*, DOI: 10.1080/10494820.2022.2091611

Hafeez, M. (2022). Effects of game-based learning in comparison to traditional learning to provide an effective learning environment. A comparative review. *Contemporary Educational Researches Journal*. *12*(2), 89-105.

Hainey, T., Connolly, T. M., Boyle, E. A., Wilson, A., & Razak, A. (2016). A systematic literature review of games-based learning empirical evidence in primary education. *Computers & Education*, 102, 202-223. https://doi.org/10.1016/j.compedu.2016.09.001

Herendiné Kónya, E. (2013). *A matematika tanítása az alsó tagozaton* [Teaching mathematics in elementary school]. Budapest: Nemzedékek Tudása Tankönyvkiadó.

Hunt, A. W., Nipper, K. L., and Nash, L. E. (2011). Virtual vs. Concrete Manipulatives in Mathematics Teacher Education: Is One Type More Effective than the Other? *Current Issues in Middle Level Education*, *16*, 1-6.

Hussein, M. H., Ow, S. H., Elaish, M. M., & Jensen, E. O. (2022). Digital game-based learning in K-12 mathematics education: a systematic literature review. *Education and Information Technologies*, *27*(2), 2859-2891. https://doi.org/10.1007/s10639-021- 10721-x

Ke, F., Xie, K., & Xie, Y. (2016). Game-based learning engagement: A theory-and data-driven exploration. *British Journal of Educational Technology*, *47*(6), 1183-1201. https://doi.org/10.1111/bjet.12314

Kelly, C. A. (2006). Using Manipulatives in Mathematical Problem Solving: A Performance Based Analysis. *The Montana Mathematics Enthusiast, 3*, 184-193.

Matos, A., Santos, V., B. Neto, T. (2023). Poly-Universe Resource for Solving Geometric Tasks by Portuguese Basic Education Students. *Open Education Studies*, *5*(1), 20220181. https://doi.org/10.1515/edu-2022-0181

McNeil, N. M., and Jarvin, L. (2007). When Theories Don't Add up: Disentangling the Manipulatives Debate. *Theory into Practice*, *46*, 309-316.

Moyer, P. (2001). Are We Having Fun Yet? How Teachers Use Manipulatives to Teach Mathematics. *Educational Studies in Mathematics*, *47*, 175-197.

Olahné Téglási, I. (2023). The impact of an interdisciplinary, tool-based course on the motivation of teacher training students. *INTED2023 Proceedings*, 468-476. ISBN: 978-84-09-49026-4, ISSN:2340-1079. doi: 10.21125/inted.2023.0170

Park, J., & Lee, K. (2017). Using board games to improve mathematical creativity. *International Journal of Knowledge and Learning*, *12*(1), 49-58. https://doi.org/10.1504/ijkl.2017.088182

Quane, K. (2024). The confluence of attitudes towards mathematics and pedagogical practice: evaluating the use of mathematical manipulatives. *Mathematics Education Research Journal*. https://doi.org/10.1007/s13394-024-00494-0

Rosli, R., Capraro, M. M., Goldsby, D., Gonzalez y Gonzalez, E., Onwuegbuzie, A. J., and Capraro, R. M. (2015). Middle Grade Pre-service Teachers' Mathematical Problem Solving and Problem Posing. In F. M. Singer, N. Ellerton, and J. Cai (Eds.), *Mathematical Problem Posing: From Research to Effective Practice* (333-354). New York: Springer.

Russo, J., Bragg, L., and Russo, T. (2021). How primary teachers use games to support their teaching of mathematics. *International Electronic Journal of Elementary Education*, *13*(4), 407-419. https://doi.org/10.26822/iejee.2021.200

Russo, J., Kalogeropoulos, P., Bragg, L.A., and Heyeres, M. (2024a). Non-Digital Games That Promote Mathematical Learning in Primary Years Students: A Systematic Review. *Education Sciences*, *14*(2), 200.

Russo, J. A., Roche, A., Russo, T., & Kalogeropoulos, P. (2024b). Examining primary school educators' preferences for using digital versus non-digital games to support mathematics instruction. *International Journal of Mathematical Education in Science and Technology*, 1–26. https://doi.org/10.1080/0020739X.2024.2361699

Russo, J. (2024c). In a nutshell: Digital versus non- digital mathematical games for supporting mathematical instruction. *Australian Primary Mathematics Classroom*, *29*(1), ISSN: 1326-0286.

Santos, V., Vaz-Rebelo, P., and Bidarra, G. (2023). Re (Creating) Games with Poly-Universe: An Innovative Practice. *International Journal for Technology in Mathematics Education, 30*(4), 235-240.

Schmidthaler, E., Schalk, M., Schmollmüller, M., Sabitzer, B., Andjic, B., Lavicza, Zs. (2023). The Effects of Using Poly-Universe on Computational Thinking in Biology and Physical Education. In *Proceedings of the 14th International Conference on Education Technology and Computers* (ICETC '22). Association for Computing Machinery, New York, NY, USA, 24–31. https://doi.org/10.1145/3572549.3572554

Setambah, M. A. B., Adnan, M., Zaini, S. H., Mujiasih, M., Hidayat, R., Ibrahim, M. A., Hanazono, H. (2024). Impact of "Donkey", "Snap" dan "King" (DSK) non-digital gamification cards on fourth-grade students' math performance in fractions. *Infinity Journal 13*(1), DOI: 10.22460/infinity.v13i1.p175-196

Sousa, L., Santos, V., and Tavares, D. (2023). Comprehensive Learning in Mathematics: The Contribution of the Poly-Universe Tool. *International Journal for Technology in Mathematics Education, 30*(3), 149-154(6).

Suydam, M. N. (1986) Manipulative materials and achievement. *Arithmetic Teacher*, *33*(6), 10-32.

Talan, T., Doğan, Y., and Batdı, V. (2020) Efficiency of digital and nondigital educational games: A comparative meta-analysis and a meta-thematic analysis, *Journal of Research on Technology in Education*, *52*(4), 474-514.

Van de Walle, J. A., Karp, K. S., and Bay-Williams, J. M. (2009). *Elementary and Middle School Mathematics: Teaching Developmentally* (7th ed.). Boston, MA: Allyn and Bacon/Merill.

Zeng J, Parks S, Shang J. (2020). To learn scientifically, effectively, and enjoyably: A review of educational games. *Hum Behav & Emerg Tech.*, 2: 86–195. https://doi.org/10.1002/hbe2.188

Authors

Edith DEBRENTI, Partium Christian University, Oradea (Romania). Email: debrenti.edit@partium.ro.

Hajnal Annamária BELLA, Partium Christian University, Oradea (Romania). Email: bellahajni@yahoo.com.