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Preliminary identification of the potential of using MIEM in the context of stimulating the development of selected cognitive processes of students in early childhood education[1]

Wstępne rozpoznanie potencjału użycia WIME w kontekście stymulowania rozwoju wybranych procesów poznawczych uczniów w edukacji wczesnoszkolnej

Abstract: The article presents the results of a quantitative-qualitative study that examined the experiences of children and early childhood education teachers with multi-layered interactive materials in which augmented reality technology was implemented. The article also addresses issues related to support (*MIEM*) for selected cognitive processes of early childhood education students. The research was conducted within the framework of the Ministry of Education and Science's program titled: *Pupil circles create innovation*. The study involved 1153 early childhood education students between the ages of 7 and 10, as well as their teachers, who constituted a group of 41 early childhood education teachers. A triangulation of research methods was used in the study. For the group of students, a diagnostic survey method was used,

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for which a survey questionnaire was developed on the *Kahoot* platform and an in-depth interview using an interview questionnaire. For the group of teachers, a diagnostic survey method was used, for which a survey questionnaire was developed. The survey was implemented using the *Computer Assisted Personal Interview technique* on the *Google Forms* platform.
On the basis of the conducted research, conclusions were developed in terms of the main objective of the research, which was: preliminary identification of the potential for using *MIEM* in the context of cognitive processes in early childhood education.
The results of the research indicate that early childhood education students received the introduced innovation into the teaching process to a very positive degree. First of all, *MIEM* resulted in high motivation for learning. The result of which was a significant number of memorized messages contained in *MIEM*. It should also be added that this fact can have an impact on students' memory and perceptiveness. It can also be tentatively concluded that *MIEM* can have an impact on cognitive processes in particular on thinking and imagination. This conclusion follows directly from the type of technology that allows generating things previously difficult to visualize. In addition, the experiences of teachers who participated in the study indicate that *MIEMs* provide new opportunities for experimentation and interactive learning. According to the teachers, *MIEMs* make it possible to support the teaching and learning of nature, mathematics, as well as other subjects. Early childhood education teachers enthusiastically welcomed the use of *AR*, as well as seeing this technology as a solution to the problems of implementing the principle of viewability in early childhood education.

Keywords: early childhood education, modern technology, augmented reality.

Introduction

Human pursuits always target finding solutions that will serve and help people in their daily and professional lives. Nowadays, new technological solutions in various areas of life are discovered practically every day. One of the new solutions that provides opportunities in teachers' didactic work is augmented reality technology.

Augmented Reality (*AR*) involves combining images of the real world with elements created through the use of IT. It allows for the generation of virtual information, such as visualization of 3D objects or of the phenomena

that a person sees on the screen in real time, using a camera of an electronic device such as a computer, tablet, or smartphone (Thompson, 2004, p. 19).

> *Augmented reality does not create a new, fully virtual three-dimensional world, but "supplements" the real world (which does not change) with new images or information (with a virtual shell). It can be an addition in the form of simple information (street names, navigation information) or an extension based on complex photorealistic objects that blend in and form a whole with the real world* (Berbecka, 2016, p. 86).

AR technology has a wide spectrum of applications in medicine, mechanical engineering, marketing, aviation, tourism, entertainment and education. It is also encountered in elementary and secondary schools and is designed to support pupils and teachers in teaching and learning math, chemistry, physics, biology, mechanics and other subjects.

The technology is increasingly supporting the educational process in early childhood education by visualizations in textbooks and other educational materials of three-dimensional figures, planets of the solar system, wild animals, natural and many other phenomena that are hard for children to imagine (Warchol, 2020; Topol, 2021, pp. 71-73).

The technology also allows for various interactions and operations involving virtual objects resulting in virtual "explosions", medical operations, virtual repairs and other activities (Korniejenko, 2018). In this process, children have the chance to explore, experiment and gain knowledge and skills on their own through virtual interaction. *AR* technology solutions fall within the range of broadly understood and applied STEAM solutions[2] in education (Park, Ko, 2012).

Multi-layered interactive educational materials **and cognitive processes of pupils in early childhood education**

Multi-layered interactive educational materials (MIEMs) is the name given to all teaching materials in paper form, e.g., books, textbooks, for which a dedicated application has been developed using *AR* technology. *AR* allows the overlaying of any traditional image made in paper form with visualizations of 3D objects with which the reader-pupil can interact. *AR* allows for the generation of a variety of layers with three-dimensional objects, hence the materials that use *AR* technology can be called "multi-layered. An additional

[2] STEAM *(science - technology - engineering - arts - mathematics*) is a combination of science, technology, engineering, arts and mathematics to create modern interactive materials.

advantage of using this technology is to see different perspectives, which are sometimes animated and enhanced with sounds" (Przybyszewska, 2014, p. 92-93). *MIEMs* aid education especially by providing new opportunities in early childhood education through supporting the development of cognitive processes.

MIEMs are also ideally suited to early childhood education, because they make it possible to support children's gradual transition from unconscious to conscious learning. *MIEMs* allow for easier learning, the development of abstract thinking, content acquisition, application, active participation, duration and student level (Dönmez-Usta and Ültay, 2022, p. 439).

The proper stimulation of children's cognitive processes is also extremely important, i.e., their intellectual development. A child at the level of early education needs multifaceted developmental stimulation of cognitive processes, i.e. perception, imagination, attention, memory and thinking (Strelau, 2004; Nęcka, 2005; Modrak, 2016).

Perception in early childhood education is treated as a "process of constructing knowledge, and is based on the assumption that perceptual experience is more than a direct response to a stimulus. The process is considered to be more of an expansion, that is, the construing of hypothetical cognitive and affective operations" (Murawska, 2014, p. 38). *MIEMs* provide for the stimulation of perception in early childhood education, precisely by having pupils interact with virtual objects, as well as performing actions that involve virtual objects. At this level of education perception is about breaking free from rigid patterns and reach beyond fixed responses (Murawska, 2014; Muchacka, 2014). *AR* technology makes it possible to go beyond standard moves and initiate individual experiments.

Imagination is also an important cognitive process in early childhood education. Once stimulated it helps reveal the child's creative potential and inspires further learning. "Imagination is the disposition of people to create mental images with varying degrees of originality. These are images that reproduce almost verbatim events already seen, experienced and remembered in the past" (Skałbania, 2017, p. 73-83). *MIEMs* support children's imagination by facilitating the transition from experience in the familiar domain to a new experience in the unknown. Stimulating imagination helps transcend limitations and develop openness to change, which connects to the innovation introduced by *MIEMs*.

Attention is the focus of perception and thinking on one external or internal observable phenomenon. In early childhood education, an ability

to focus one's attention is an important skill because improper focus leads to learning problems (Murawska, 2014; Muchacka, 2014). *MIEMs* make it possible to select objects, colors or effects that help children focus more effectively on the material discussed and concentrate on a single element or issue.

"Memory is also a key element in the proper course of learning. It is responsible for the encoding, storage and reproduction of information" (Harmacinska -Kowalewska, 2018, p. 22). "Most often, in early childhood education memory is stimulated by learning a poem or a song by heart and memorizing the content of the texts read" (Murawska, 2014, p. 36). *MIEMs* allow children to exercise their memory in an enjoyable way through a variety of memory-related tasks that are both stimulating and pleasant. Such possibilities are offered exclusively by *AR* technology, which enriches existing textbooks or a books with memory-stimulating content.

In a general sense, thinking is a conscious mental process leading to indirect, generalized cognition and an understanding of reality (Barley, 2018, pp. 183-200). "In early childhood education, the development of thinking is aimed at performing certain operations, putting things in order, classification or constancy" (Murawska, 2014, p. 8). *MIEMs* support these operations, because they help children perform them on specific elements, see objects and serialize them, as well as grouping 3D elements on the basis of pre-set criteria.

Accordingly, *MIEMs* allow you to interact with the cognitive processes presented, but also "support the main premise of early childhood education, that is, compensating for developmental deficiencies, teaching children how to think, teaching them how to solve problems and overcome difficulties, learning how to teach, that is, how to satisfy the child's cognitive curiosity" (Szymczak, 2021, p. 130). Therefore, it can be concluded that they can be relevant in early childhood education

"Today, the student is "condemned" to audiovisual experience of the world around him" (Kowalczyk, 2015, p. 264) . Therefore, from the very beginning it is worth pointing out to students such solutions that will support their development. *MIEMs* seems to be one of the most important applications of future education.

As contemporary research shows, "the use of modern solutions rationally by students, such as multimedia programs, can foster primarily:: reducing fears and tensions, strengthening self-esteem, awakening interests, shaping manual skills, developing decision-making skills organizing new situations" (Szymczak, 2021, p. 132).

Of course, one should "also not forget the role of the teacher and educator, who, whose task is not only to care, but also to impart knowledge and

shape new skills using elements of play" (Adamek, 1997, p. 167). The teacher discovers an important role in the introduction of all new technologies. It can be concluded that his attitude regulates how a student uses modern technologies in his further education (Tuczynski, 2021, pp. 48-53).

The teacher at each stage of education, and especially in grades I-III, should be a person who imparts knowledge, values and supports the process of forming attitudes in this case also the use of modern technologies. He should be a very ethical person, presenting positive role models, on the basis of which the child creates his own personality, his own world of values and develops an individual system of needs. "In a modern school, the early childhood education teacher should act in the role of an expert, manager, inspirer, integrator, who knows modern technologies and is able to point out the directions of their application" (Ordon, 2017, p. 119).

Thus, the introduction of such teaching resources as *MIEMs* should be in the responsibility of every teacher who wants to properly prepare early childhood education students to make correct, independent decisions about the legitimacy of using a given teaching resource.

Research methodology

The research strategy consisted of early childhood education teachers conducting classes in which children used educational booklets that incorporated augmented reality technology. The topics of the booklets covered farm animals and math.

The first book contained visualized farm animals, tasks related to these animals involving, for example, matching food for an animal, choosing the correct place to raise it on the farm, identifying raw materials from animals, and indicating food-related products. It also included sounds that animals raised in a rural household make.

The second book devoted to contained teaching material entirely to learning how to teach mathematics in terms of plane figures. In this book, students faced tasks involving pointing out the correct answers, such as equilateral triangles, circles, and circles. The tasks also involved measuring the sides of figures and determining the angles in the figures presented.

The teacher held a two-hour class using a book on farm animals, and another on plane figures in math. Generating 3D objects was done by using tablets that correlated with the booklets. An application installed on the tablet triggered a camera, which was turned towards the booklet and generated additional 3D objects on the page. The application generating the 3D objects

provided the opportunity for the child to interact with the virtual reality, as well as perform tasks involving the objects generated.

The main focus of the study was educational materials constructed using augmented reality technology (so-called multi-layered interactive educational materials - *MIEMs*).

The main purpose of the research was: preliminary identification of the potential of using *MIEM* in the context of cognitive processes in early childhood education.

The following theoretical and diagnostic goals were formulated in the research:

- Determination and measurement of remembered information contained in *MIEMs* by early childhood education students
- Indication of teachers' experiences in the use of *MIEMs* in early childhood education

A practical goal was also defined, which was formulated as follows:

- Identify educational directions for the application of *MIEMs* in early childhood education.

The main research problem was to seek an answer to the question: *What are the opportunities for MIEM to support cognitive processes according to students and teachers in early childhood education?*

The researchers adopted the hypothesis H_0 – *MIEM provides new opportunities to support educational potential in learning and cognitive processes.*

A triangulation of research methods, i.e., diagnostic survey and in-depth interview, was used for the purposes of the study (Kubinowski, 2016; Kubinowski, 2019). The research tools applied were tailored to the developmental level of the pupils involved.

Due to the early school age a survey questionnaire on the *Kahoot* platform was thought best for the group of children involved in the study. The platform makes it possible to conduct the survey in a simple form. Undoubtedly, an additional advantage is the ability to identify answers by colors or shapes, which simplifies the process of selecting answers (Figuccio, Joseph, Johnston and Marla, 2022, pp. 170-177). In addition, a guided interview was conducted with some of the children, using an interview questionnaire.

Surveys with students were conducted in a systematic manner and collected comprehensively during the last class. Each student was given a tablet and within the framework of the launched survey on the Kahoot platform, they joined the prepared survey questionnaire.

The teachers answered questions using a survey questionnaire developed on the *Google Forms* platform. Each teacher answered the survey

questions at the end of the class. Both student and teacher survey results were collected automatically and through the use of digital tools, were automatically processed.

The study was conducted between September 2021 and January 2022 in 10 elementary schools in the Subcarpathian region, involving 1153 students aged 7 to 10, as well as 41 early childhood education teachers.

Both student and teacher surveys were collected automatically and, through the use of digital tools, were automatically processed.

The research characteristics of the children in the early childhood education group are presented in Table 1.

Table 1 Characteristics of the pupils in early childhood education surveyed

Gender	Number surveyed	Place of residence		Age of pupils			
		City	Village	7	8	9	10
Girls	528	253	275	166	132	120	110
Boys	625	320	305	179	150	155	141
Total	1153	1153		1153			

Source: own research.

Table 2 Characteristics of the early childhood education teachers surveyed

Gender	Place of residence		Professional seniority in years					Age			
	City	Village	1-5	6-10	11-15	16-20	21- more	25-30	31-40	41-50	51-60
Women	21	20	5	9	10	12	5	5	19	14	3
Total	41		41					41			

Source: own research.

Participants in the study included students at the early childhood education level from schools expressing a desire to introduce an innovation related to the use of *MIEMs* at their school. The basic requirement for participation in the study was to attend grades 1-3 of elementary school and be between the ages of 7 and 10.

Analysis of the results of research on the opportunities for using augmented reality in early childhood education in the opinions of children

The children were asked to answer 25 questions on the *Kahoot* platform. The first 20 questions were designed to assess the applicability of *MIEM* in the context of stimulating selected cognitive processes such as:

- perception, attention/focus
- imagination
- memory
- thinking (Strelau 2004, Nęcka, 2005, Modrak, 2016).

Other questions were related to issues of supporting learning and teaching through the use of augmented reality technology

The analysis of the results addressed the cognitive processes outlined above. Based on each set of questions, the potential impact of *MIEM* on the indicated cognitive processes was determined.

The first set of five questions dealt with initial verification of the impact of *MIEMs* on students' perception and attention.

The results showed that 90% of the pupils answered the questions correctly. This demonstrates students' correct perception and focus when working with *MIEMs*. In addition, it was noted that it was students declaring their place of residence as rural who performed worse than urban students. In terms of age, it was students aged 9-10 who were more likely to answer well. This may mean that older students have better developed perception and attention processes than their younger counterparts. Gender differences in test results were not found for questions verifying perception and attention.

It can be concluded that the effect resulting from the use of *AR* technology caused students to be very focused and engaged with the books using *AR* technology. It can be assumed that this is due to the effect of the innovation of the lessons conducted, which the students were very positively surprised and interested in.

Similar results were obtained in a study using *AR* on improving science teaching/learning in a group of pupils aged 12 (Tijus, Chen and Chang, 2022, pp. 1-11).

Another high score of correct answers was recorded when testing children's perceptiveness (imagination).

In this regard, pupils very accurately captured all the details that *AR* technology generated. The average value of correct answers was 96%. Only very few pupils were unable to answer the questions correctly. In terms of these questions, no significant differences by age were noted, but it can be

noted that, once again, it was students coming from urban areas who were less likely to indicate wrong answers. In the analysis of the results obtained, it was the girls who performed better in terms of 99% correct answers.

AR is one of those technologies that seems to have the greatest potential precisely in terms of stimulating imaginations, because it enables the generation of virtual objects in real time.

It is worth adding that stimulating children's imagination in early childhood education is of great importance, as confirmed by the results of research by many authors (McAnally, Bridget and Marjorie; Elaine, 2021; Jitsupa, Nilsook, Songsom, Siriprichayakorn and Yakeaw, 2022).

Another series of questions involved playing back from memory what pupils remembered from working with the *AR* effect booklets.

The average of students' correct answers in this area was also very high at 87%. From the results obtained, it can be concluded that the students remembered most of the information that was presented in graphic and audio form, as well as in the form of performance tasks. Based on the results obtained, it can be concluded that the AR technology used had a significant impact on students' memory. In this range of questions, it was the younger students (7-8 years old) who had a higher number of correct answers of up to 90%. Once again, it was students coming from urban areas who were better than students from rural areas. Analyzing the results from a gender position, it was girls who remembered more information than boys.

The result obtained is impressive in the context of further development of this technology and its introduction, for example, in school textbooks. AR allows combining old methods of work with the textbook implementing innovations to them, which directly motivate students to act and solve problems (Walat, 2022, p. 249).

The last questions focused on the thought process itself. The students had to relate several pieces of information from different pieces of interactive material and answer the questions posed.

Students had the most difficulty with this part of the question. In this area, students' correct answers were recorded at 67%, which is the lowest in the entire study. This means that giving correct answers to questions that require students to synthesize information from several cognitive processes is difficult and complicated for students. Students again had the greatest problems with questions in mathematics education. This shows that students have a problem in classifying, comparing and extracting individual objects and their features from the background. Taking into account the age, it can be seen that every group of students surveyed had problems, the smallest

problems were noticed in the surveyed 10-year-olds. In the answers to this question taking into account the place of residence of the surveyed students, no significant differences were found. In the breakdown of the surveyed students by gender, both groups had similar results.

This problem has been found previously in various pieces of research (Morgan, Du and Friesen, 2021); therefore, looking for the means to support the development of children in early childhood education in terms of their cognitive processes is strongly recommended.

In addition, several questions were asked about issues related to improving learning and teaching by using augmented reality technology:

1. Do you think the augmented reality technology aids your learning?
2. Do you want to use such technology in your school more often?
3. Do you think that extended factuality solutions help you remember more, understand more or stimulate your imagination?
4. Have you had any problems using the tablet and book together?
5. Do you think it is better to look at animals and figures on a tablet or in a traditional book?

Due to the children's age, they were only given two answering options, *Yes* or *No*. The results from the survey are presented in Figure 1, which shows the percentage of responses.

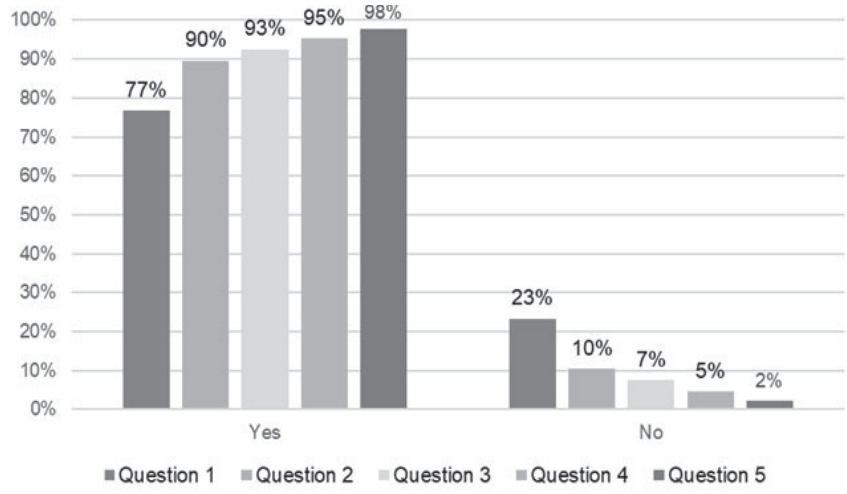

Chart 1. Graphical representation of the results obtained from questions on the ergonomics of the tools of augmented reality technology.

The result of the survey presented in Figure 1 shows that students mostly chose an affirmative answer to each of the questions asked: Yes. Based on the results presented, we can conclude that ARs support the learner in acquiring new knowledge. Students have no fear of new technologies on the contrary, they expect their application in the educational process. In the analysis of the results of the study, the biggest differences were noted by age, as students aged 8-9 were more likely to answer in the negative (No) than their counterparts aged 7 and 10. In addition, it was noted that girls were more likely than boys to agree with the questions presented.

Summarizing this part of the questions, it can be concluded that augmented reality technology enriches education, opens new opportunities for the development of early childhood education students, allows students to acquire knowledge faster and has the potential to support students' cognitive processes at the early childhood education level. This conclusion is also supported by other studies, which found that the use of AR enabled better learning of basic skills, increased students' motivation and positive attitude, and supported students' autonomy (Aldossari, Zainab Alsuhaibani, 2021, pp. 1-8).

Since the questions presented involved only *yes* or *no* answers, 153 pupils were selected for extended talks and were interviewed individually in the form of a guided conversation.

To expand on Question 1 in the survey, children were asked: *Why do you think technology is good for education, What is so special about it?*
Pupil 12: "...we can see things we haven't yet seen in a normal school textbook..".
Pupil 40: "...it makes me want to learn and continue to see the things that I can find in these books...".
Pupil 73: "...because I can use the tablet to look through the book...".

All of the children's responses were in a similar vein to those presented above. These statements only confirm that children at this level of education want to use augmented reality technology. In addition, they very much enjoyed using tablets, which they had not used before during lessons. Similar responses were obtained in a study on the use of AR for language learning (Aldossari, Zainab Alsuhaibani, 2021, pp. 1-8).

Children also spoke about having their cognitive processes stimulated, as the three-dimensional aspects of the objects they worked with often appeared in their statements.

Question 2 of the questionnaire was expanded to include the following questions, i.e.,: *Why would you like to use such solutions in your school more often?*
Pupil 51: "...because we usually only learn from books...".
Pupil 72: "...because the teacher never uses anything new, we just keep writing and reading books...".
Pupil 80: "...because I can work with a tablet and learn from it...".
Pupil 151: "...because it makes me more interested in the lesson....".

These selected responses indicate that children think that at school modern technology is not applied enough. The most common theme of their statements was the lack of modern technologies in school. Children often talked of the classes conducted with *AR* books as a dream come true. It is also worth mentioning that the children who participated in the classes were very engaged by working with tablets and augmented reality applications.

For Question 3, the additional questions were as follows: *What did you manage to remember? What did you understand fastest?*
Pupil 40: "...I remember all the animals that appeared in the book, I watched them carefully, I know what size they are, I have never seen such a thing before...."
Pupil 56: "...I remembered almost everything; it was really great. Additionally, I could test myself in different exercises...".
Pupil 80: "...I managed to memorize everything that was in the books, both animals and figures, because everything was new and very cool...."

It seems that in the children's opinions, augmented reality technology was very engaging in the process of learning and acquiring new knowledge. It could be inferred from their responses that they remembered a great deal of information from the booklets, even the kind that was not exposed in the form of augmented reality. What's more, children remembered a lot of detail, which indicated positively that their imagination, memory and thinking were stimulated.

The memorization of details by pupils who used AR is a finding that has been confirmed in other studies on education (Morgan, Du and Friesen, 2021; Tijus, Chen and Chang, 2022, pp. 1-11).

For Question 4, the following additional questions were asked: *In your opinion, was it complicated to manipulate the tablet for AR effects? Were the books of big enough or would you have preferred larger ones?*
Pupil 19: "...it was very easy, and the books were better than the school books..."
Pupil 28: "...it was fun to learn with a tablet and it wasn't difficult at all"

Pupil 55: "...learning with such books is better than with a textbook because they are small and light...."
Pupil 19: "...I didn't have any problems because I often use the tablet at home, and the books were cool..."

It can be concluded that the technology used was not at all complicated for the pupils; on the contrary, they found it familiar and easy-to-use. This indicates that children have no problems using the technology and want to be able to learn using *AR*.

For Question 5, children were additionally asked: *Do you remember what information was placed above the dog's kennel?, Which are bigger, hens or roosters?, Does a square have the same number of sides as a triangle?*

Researchers found that each child selected for the interview remembered the exact name placed above the dog's kennel in the nature book. Every child answered the question regarding the size of hens and roosters correctly and spoke in detail about the figures that were included in the math book. The pupils remembered almost all the information presented in the books.

Analysis of the results of research on the opportunities for using augmented reality in early childhood education in the opinions of teachers

The classroom teachers were also asked several questions about the lessons they had taught. The first category of questions concerned the use of augmented reality technology in early childhood education.

For the questions presented, you could indicate the answers: Yes, No, Maybe. The same results were obtained for each of these questions: Yes - 87.8%, No - 2.4%, Maybe - 9.8%.

The results of the study clearly indicate that augmented reality has didactic potential and can support the learning process in early childhood education. These results are significant in that the study involved teachers who are experienced in working with children in early childhood education who have observed the need for education using *AR*. They also pointed out that the technology provides new opportunities for knowledge acquisition. Teachers also indicated that this type of technology supports their teaching.

These findings are supported by another study which involved 350 teachers, who also used various *AR* applications, and concluded that *AR* technology represented the future of education as it enabled the integration of information and communication technologies (Marín-Díaz, Sampedro, Figueroa, 2022, pp. 6-16).

As for the *no* (2.4%), *maybe* (9.8%) answers, these were given by the teachers in the 51-60 age bracket who were initially skeptical about filling

out the survey via tablet, and in some cases had trouble handling it. It is also worth noting that a large part of this group were teachers living in rural areas - 70%. It seems that this may be due to their lack of adequate preparation for the use of IT in education.

The teachers could also mention other opportunities afforded by the potential of *AR*. Their answers focused on various areas, i.e.: *the development of imagination, waste segregation, mathematics, experiments, art education, music education, figures, measuring, tales and fables, shapes, sets, learning the clock, road signs, syllables, animals, music notes, personal hygiene, living organisms*.

The teachers' answers have been grouped, as they were all long and comprehensive, clearly indicating different applications e.g., personal hygiene, learning the clock. For this question, urban teachers very often commented that it was the area of mathematics and supporting experiences that could be strengthened by AR. Rather, teachers with more than 21 years of experience most often chose topics that are currently being emphasized, i.e. ecology, waste segregation.

The second category of questions focused on supporting pupils' learning and cognitive processes in early childhood education using augmented reality technology.

For this category, 6 single-choice questions (*Yes*, *No*, *Maybe*) and one multiple-choice question were asked.

The results for these questions were similar: *Yes* - 92.7%, *No* - 2.4%, *Maybe* - 4.9%. It can be therefore concluded that teachers were in agreement as to whether augmented reality technology supports the learning and the development of children's cognitive processes. All teachers in the 25-40 age range were in favor of introducing *MIEMs* into education as soon as possible. All negative answers were given by teachers with a lot of seniority.

The data presented shows that according to teachers, AR technology has the potential to stimulate cognitive processes The results provide evidence that augmented reality technology is important in terms of the cognitive development of children in early childhood education.

The third category of questions concerned the applicability of augmented technology to science and math education.

According to the survey on natural science education, as many as 87.8% of teachers see the need to implement the technology, while others answered *no* (2.4%) or *maybe* (9.8%). Negative or abstaining responses were most often from teachers with more than 15 years of seniority. It is noteworthy that teachers young and with little seniority all see the need to use AR in

nature education. The most common answers were: *basic principles of caring for plants and farm animals*, *differences between autotrophs and heterotrophs*, *importance of forests for humans*, *layers of the forest, birds*, *amphibians*, *reptiles, farm animals*, *waste segregation*.

The research on the application of *AR* in mathematics indicates that 85.4% of teachers see the possibility of using this technology in mathematics education, 12.2% answered *maybe* and 2.4% *no*. Abstentions were answered not only by teachers with a lot of seniority (more than 21 years) years, but also by a large group of teachers with little seniority (up to 5 years). In this case teachers also indicated the main topics where augmented reality technology could be applied, i.e.: *mathematical equations*, *shapes*, *figures*, *mathematical games*. Geometry dominates, probably because AR technology supports pupils' imagination by introducing the 3rd dimension. Admittedly, in an apparent but nevertheless visible way, children can also perceive the spatiality of solid figures.

This is a conclusion that is supported by other researchers, stating that *AR* is one of the most anticipated technologies in the sciences for presenting complex things and phenomena (Yildirim, Seckin Kapucu, 2021, pp. 56-68).

The results obtained from the study of the teachers' group show that augmented reality technology is an innovative solution that has been eagerly adopted and, as the survey shows, teachers are finding many grounds on which to apply the technology.

Conclusions and generalizations

Analyzing the presented research results, it can be concluded that both teachers and students of early childhood education positively received the applied educational innovation in the form of prepared multi-layered interactive educational materials to support learning and teaching of nature and mathematics.

It must be stated that the H0 adopted in the study on the basis of the quantitative and qualitative research conducted can be accepted. This is indicated by the high percentages of responses obtained in both research groups.

The set main goal of the work has been fulfilled, because based on the results obtained, we can conclude that *MIEMs* have potential significance in terms of stimulating students' cognitive processes.

The realization of the cognitive-diagnostic goals set in the study was realized on the basis of the responses of the two research groups. It is necessary to state that both students and teachers have determined that there is great educational potential in AR, which can be used in many scopes of

the teaching and learning process. It can also be tentatively concluded that AR has an effect on students' concentration of attention. This conclusion was fleshed out, as each student using *MIEMs* during class was focused and engaged in the work. This is also confirmed by the number of memorized content that students realized during *MIEMs* activities.

In addition, using *MIEMs*, the students exercised their memory, and the effect of using AR technology caused them to direct their attention to various details, which they remembered more easily.

Based on the results, it can be concluded that the study showed the potential impact of this technology also on developing and stimulating imagination. Students after the activities were able to accurately differentiate the type and meaning of the memorized information, point out and determine the exact positions of key elements and characters.

One of the theoretical and cognitive objectives was also to determine the experience of using *MIEMs* during the educational process by teachers. It can be concluded that teachers whose length of service exceeded 15 years had major problems. It seems that this is due to the lack of adequate competence in the use of modern technologies. It can be assumed that teachers with such seniority were from the beginning "closed" to any educational innovations and changes, which manifested itself in distrust, regarding new technological solutions.

A very important statement on the basis of the presented results, as well as in the context of the presented theory, may be the fact that teachers of early childhood education, should more often than teachers at higher levels of education participate in activities to improve their competence related to the use of information and communication technologies in their work. Perhaps such action will eliminate reluctance and fear of modern solutions.

Based on the results of the survey, it can be concluded that most teachers see many directions of application for the technology, and in this regard, teachers did not lack ideas. With regard to both science and mathematics education, they listed many different topics in which they would like to be able to use augmented reality technology.

It is worth noting that the presented research shows serious deficiencies at the early childhood education stage in the proper implementation of the principle of viewability. The presented teachers' responses in this regard further compound the lack of solutions to this issue, and AR and the use of *MIEM* is a technology that brings students closer to understanding and seeing a variety of phenomena. Thus, it can be confirmed that this technology is an opportunity to better educate children in early childhood education.

This shows that the technology is potentially a good solution for supporting the education of preschool and early childhood education students. Students as the main target audience indicated that the use of tablets and augmented reality in education is the fulfillment of their dreams for a modern school.

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