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CASE STUDY

Using an augmented reality application for teaching plant parts: A case study in 1st-grade primary school students

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Abstract: The rapid development of augmented reality (AR) applications has led to wide adoption in education, acting as a supporting tool to increase the transmitted information. However, children need to improve their knowledge of plants, their categories, their conceptual framework as well as the human relationship with them. This research studies the learning outcomes of a plant-themed augmented reality mobile application and its key features designed for 1st graders of primary school. The results of the research showed that there was no statistically significant improvement between the experimental group and the control group.

Keywords: Augmented Reality, environmental study, mobile education, primary education

1 Theoretical background

Augmented Reality (AR) is a new form of experience that consists of digital content of two-dimensional and three-dimensional objects enhanced by video, audio and text files, up to information of scent and touch that help the user to understand better what is happening around him (Beltozar-Clemente et al., 2022; Yuen et al., 2011). Caudell & Mizell (1992) define augmented Reality (AR) as the type of technology that "augments" the information of the environment that the user sees, while Klopfel & Squire (2008) define it as "a situation where the content of reality is covered dynamically with virtual elements using physical space". For Azuma (1997), augmented reality is defined as a system that combines real and virtual elements in three-dimensional form, interacting in real time (Tsoukala, 2021).

Augmented Reality does not replace reality; instead, it complements and enhances it. It can replace or enhance the reduced senses of users with special needs and be a helpful tool for those people (Campos-Pajuelo et al., 2022; Carmigniani et al., 2011). In augmented reality, digital elements are mixed with the natural environment. According to Milgram's Reality-Virtuality Continuum, AR sets virtual objects in real-time and places to be closer to the real world, thus enhancing the user's perception and allowing interaction (Carmigniani et al., 2011; Berryman, 2012). The natural environment undergoes interventions that improve the sense of presence (Kalogiannakis & Papadakis, 2017; Kardong-Edgren et al., 2019).

The forerunner of today's augmented Reality is Morton Heilig, who built 1950 the Sensorama, a mechanical device that simulated a walk in New York involving all the senses of use. Ivan Sutherland is the inventor of the first AR system, the Head Mounted Displays (HMD). This wired device was placed on the head, connected to a desktop computer and connected to the ceiling and combined electronic information with Reality (Berryman, 2012). In 1975, Myron Krueger built a room where users could directly see the results of their actions on the screen, experiencing an artificial reality environment (Carmigniani et al., 2011). In 2000, Bruce Thomas introduced the first mobile augmented reality game called ARQuake (Carmigniani et al., 2011), while Klopfel & Squire (2008) designed the program "Environmental Detectives".

With the arrival of mobile smart devices in the market in 2010, augmented reality applications also appeared, using the built-in camera, GPS and display for entertainment and advertising purposes (Papadakis, 2021; Papadakis et al., 2021). Users can browse historical sites, identify objects by highlighting information about them, play games, model objects, and purchase augmented books (Drolia et al., 2020; Johnson et al., 2010; Papadakis et al., 2018).

AR applications can be either marker-based or markerless. Marker-based applications need three essential components, an information leaflet, a handle to receive that information, and a cube necessary to convert it into 3D information on the screen. In contrast, markerless apps use data from a mobile GPS or compass (Johnson et al., 2010; Lee, 2012). Cheng & Tsai (2013) redefine the above two categories as image-based and location-based augmented reality applications, thus expanding the characteristics of AR applications.

There are three types of augmented reality devices, the display devices which refer to the devices on which the information is projected and are divided into head-mounted displays (HMD), hand-held displays (smartphones and tablets) and spatial displays (holograms, video projectors), the input devices (e.g. mouse, keyboard, gloves, wireless wristbands but even the mobile device itself) and detection devices (e.g. digital cameras, GPS tracking system. (Carmigniani, et al, 2011).

2 Augmented Reality in education

The rapid evolution of augmented reality applications has led to their broader adoption in education as a supporting tool to increase the transmitted information (Bacca et al., 2014). In fact, in the last decade, with the advent of mobile devices, augmented reality technology can now be applied beyond school boundaries, thus increasing learning opportunities (Lazarinis et al., 2022; Laine, 2018).

Research by Wu et al. (2013) identified the critical advantages of augmented reality systems for educational purposes based on five aspects. Augmented Reality can present the content in three-dimensional perspectives, i.e. students can see an object in all dimensions and from different angles, thus strengthening their spatial skills and, by this extension, their understanding of learning content (Billinghurst & Duenser, 2012; Di Serio et al., 2013; Ibáñez et al., 2014). It also offers collaborative and situated learning with students directly involved in more realistic experiences feeling more devoted and engaged in learning processes (Bressler & Bodzin, 2013; Revelle et al., 2015). In addition, AR is an ally of the physical sciences as it can visualize the invisible. It helps students visualize objects that are not visible to the naked eye in the Physics lesson, places that are not possible to visit, or even abstract concepts of Mathematics (Laine, 2018). Finally, it bridges formal and informal learning. The above positive features of AR technology lead not only to enhanced learning benefits, such as a more profound understanding of content, long-term memory retention, creativity and greater assimilation of knowledge, but also to increased motivation, better concentration and effective collaboration with classmates (Radu, 2012; Bacca et al., 2014; Pedaste et al., 2020). Increased intrinsic motivation was also observed from the augmented reality application created by Di Serio et al. (2013) and more significant social interaction and cooperation in the educational game of Revelle et al. (2015). Higher levels of concentration, a greater sense of control and internal satisfaction led to more meaningful knowledge and immediate information recall (Ibáñez et al., 2014), while the harmonization of cognitive goals with additional digital material enhances students' learning performance (Chiang et al., 2014).

In order to highlight the above perspectives, it is essential in games and augmented reality applications that users are directly involved in role-playing games and simulations so that they interact realistically with their natural environment and that the content of the learning tasks assigned to them is clear and straightforward (Wu et al., 2013).

However, the educational usefulness of augmented reality is questioned in many cases compared to other educational means. Human development factors positively or negatively affect augmented reality's effectiveness compared to other means. The existence of three-dimensional objects, the possibility of spatial and temporal relevance, physical mobility, "digital augmentation" of Reality, as well as the degree of interaction and difficulty of use may affect the child's ability to understand the educational content of an augmented reality game (Radu, 2014).

While the readership of literary books is decreasing and technology is growing at a rapid pace, AR books come to bridge this gap and introduce children to a magical world where heroes of the story are visualized in front of their eyes and a more comprehensible story content (Cheng & Tsai, 2014). Users can interact with the AR book by rotating it or turning its pages, and the virtual item is displayed to them, enhancing their long-term memory and sense of joy and pleasure (Billinghurst & Duenser, 2012; Cheng & Tsai, 2014).

Similar results are also shown in AR games whose usefulness extends from recreational to educational purposes because students' interest and desire for higher performance in the lesson increase. Thanks to that, students improve their performance in the classroom and learn to cooperate (Bressler & Bodzin, 2013; Hwang et al., 2016; Laine, 2018).

The inquiry-based approach through AR prompts students to interact with the learning subject in real time. The combination of the teaching objectives with the augmented content contributes positively to the promotion of knowledge (Chiang et al., 2014), as well as to a deeper conceptual understanding of the subject, to enhanced motivation and positive emotions (Pedaste et al., 2020).

The category of educational AR applications also includes object modelling, in which specific objects are visualized in different environments and is helpful in the creation of skills training programs for adults in the field of medicine and military engineering (Yuen et al., 2011).

The existence of three-dimensional objects, the possibility of spatial and temporal relevance, physical mobility, "digital augmentation" of Reality, as well as the degree of interaction and difficulty of use may affect the child's ability to understand the educational content of an augmented reality game and to lead him to cognitive overload (Wu et al., 2013; Radu, 2014). Specifically, the potential difficulty of using mobile devices, the large amount of information and the complexity of the tasks can confuse students, disorient them from learning goals and increase their anxiety when the application does not work correctly (Radu, 2012; Bacca et al., 2014). Sometimes, they need more time to complete their work and fully understand the content (Antonioli et al., 2014). In order for students to be able to respond to the required tasks in an AR environment, they should be sufficiently academically mature and have complex skills, such as cooperation, problem-solving ability, spatio-temporal perception, mathematical estimation and their work should be discreet but constantly monitored by fully trained and familiar with PE technology teachers (Wu et al., 2013; Antonioli et al., 2014).

3 Alternative perceptions

Children are in daily contact with their social and physical environment, they interact in it, and we must be aware of it (Vaiopoulou et al., 2021). However, children need to improve their knowledge of plants, their categories, their conceptual framework as well as the human relationship with them (Barianos et al., 2022; Dahal et al., 2022).

Children aged 4-5 years think the plant is small and green, with leaves, a straight trunk and a flower. Anything outside this image was not considered a plant, such as a cactus, while trees, vegetables and flowers belonged to a particular category (Gatt et al., 2007). Growing up, children aged 6-7 do not connect paper with trees, nor peanut butter with peanut seed. That means they fail to understand the connection between their everyday products and plants, which may be due to the lack of connection between plants and their daily experiences and the inadequate school curriculum (Anderson et al., 2014). Incorrect answers are also noted in 11-12-year-old students, demonstrating the consolidation of wrong alternative perceptions and the difficulty of transmitting and understanding the specific knowledge object on plants (Fokides et al., 2020; Papadakis et al., 2022).

However, fundamental misconceptions about plants were also identified among future teachers who will soon be teaching in elementary school (Papadakis & Kalogiannakis, 2017). These concerned the morphological, structural and other biological relationships between plants. Most teachers consider the pine a seedless plant due to its large size and non-flowering nature. It also appeared from their answers that future teachers still need to fully understand the concept of fruits and vegetables. Such misconceptions are likely to be transmitted to their students. If they are not corrected in time, they will also perpetuate incorrect knowledge in the next generation (Yangin et al., 2014).

Alternative perceptions result from complex processes by which children organize their information and perceptual experience (Drolia et al., 2022). Reorganization through teaching and not sterile replacement is therefore recommended (Vosniadou, 2002). Balding & Williams (2016) suggest that creative activities based on anthropomorphism, such as role-playing, painting or writing stories, can significantly contribute to forming positive emotional connections with plants, enhancing our empathy with plants.

More systematic interaction with plants and an adequately designed curriculum are the main factors that will prevent "blindness" towards plants and strengthen our love for plants. Nevertheless, the most critical factor is the presence of qualified teachers who, in the role of mentors, will focus the attention and appreciation of their trainees and encourage the importance of plants in our lives (Jose et al., 2019).

4 Methodology

The learning results that show either neutral or positive results and the highlighting of misconceptions led us to design an augmented reality application through the Metaverse platform (Figure 1) and to implement the following teaching intervention for 1st-grade students in the Environmental Studies course.

Therefore, the primary purpose of the work is to evaluate the conceptual understanding of plants and their essential morphological element. Specifically, students should be able to clarify what plants are, distinguish their leading parts, recognize their morphological elements, and discover new information about them. The research questions that arise are the following:

(1) Does teaching with an augmented reality application result in better learning outcomes than traditional teaching?

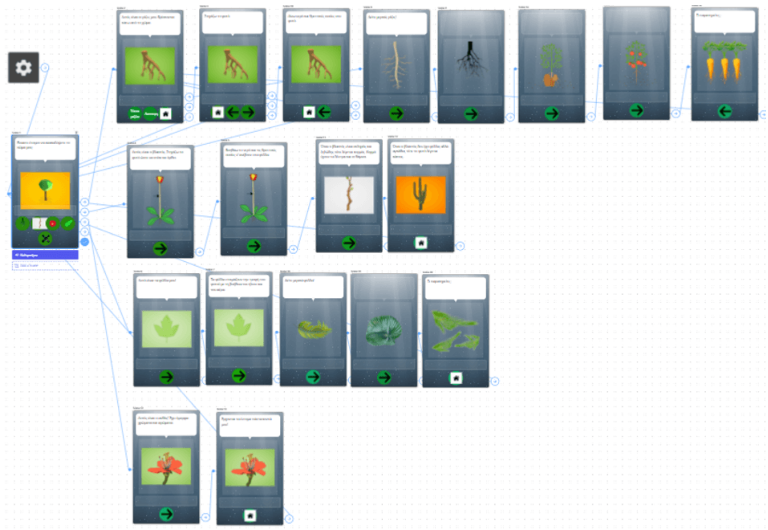

Figure 1 Designing the AR app in the Metaverse platform

(2) Does teaching with an augmented reality application contribute to a better conceptual understanding of plants compared to the traditional way of teaching?

The selection of the sample was made by the method of convenience sampling due to easy access to the sample. The research sample will be two first-grade classes in a semi-urban area of Heraklion. One class, consisting of 14 students, seven boys and seven girls, will be the experimental group that will use the application, and the other class, consisting of 13 children, six boys and seven girls, will be the control group that will follow the traditional way of teaching. Ethical principles relating to basic individual protection requirements were met (Petousi & Sifaki, 2020).

In this work, the constructivist teaching model of Driver & Oldham (1986) will be used, which includes five phases: In the first phase of orientation, where the teaching topic is presented and through participation in discussions with the teacher, students are motivated about plants; in the second phase of highlighting the student's ideas, where in both groups, we will highlight their alternative perceptions about plant using the method of questions. The third phase is the reconstruction of the ideas where the new teaching subject is presented and applied, and the students discuss, exchange opinions, observe and record. In the experimental group, students explore the AR activity, which is available on their tablet and learn about the parts of the plants (Figure 2 and 3). In contrast, the control group followed the same teaching method but used the visual material from the school's book on the interactive board. In the fourth phase, the application of the new ideas, the students of the control group work on the indicative exercise. In the fifth and final phase, the review, the students of both groups will reflect on what they have learned and capture it in a drawing.

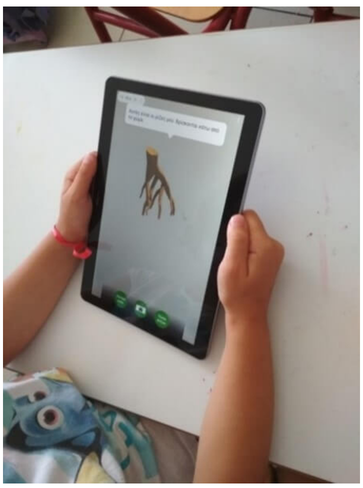

Figure 3 AR app in the classroom

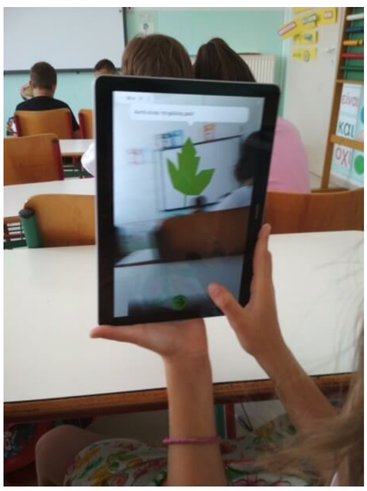

Figure 4 AR app in the classroom

Two assessment sheets were given to the students of both groups, one before the intervention to detect their pre-existing knowledge about what a plant is and its parts and one after the intervention to assess what they learned. The two sheets are different from each other. They contain multiple-choice, true-false and matching exercises and the student's performance on them was based on 21.

5 Results

The following data (Table 1, 2 and 3) were obtained through the SPSS statistical program.

Table 1 Paired samples statistics

Pair 1	Mean	N	Std. Deviation	Std. Error Mean
posttest	17.333	30	2.2604	0.4127
pretest	12.967	30	2.1732	0.3968

Table 2 Independent samples test

Improvement	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI Lower	95% CI Upper
Equal variances assumed	1.772	0.194	-0.878	28	0.388	-0.8667	0.9876	-28.897	11.564
Equal variances not assumed			-0.878	27.293	0.388	-0.8667	0.9876	-28.921	11.587

The paired samples t-test showed that the average performance in the pretest was 12.967 while the average performance in the posttest was 17.33. The difference is at 4.3667 with t = 8.878, df = 29 and p-value < 0.01, less than any usual significance level, which means that the difference between the pretest and posttest is statistically significant. Therefore, after the end of the teaching, regardless of which group they participated in, both groups improved their performance statistically significantly.

Table 3 Paired samples test

Pair 1	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% CI Lower	95% CI Upper			
posttest - pretest	43.667	26.940	0.4918	33.607	53.726	8.878	29	0.000

To study the statistical significance of the numerical superiority of the experimental group, we will carry out a t-test for two independent samples, which shows that t = -0.878, df = 28 and p-value = 0.388 > 0.1, greater than any average level significance, so the improvement of the control group is approximately equal to the improvement of the experimental group.

Studying the improvement of the groups in each question and the resulting p-values, we notice that the difference is statistically significant only in the 1st question concerning the recognition of plants. In contrast, in the remaining questions concerning the recognition of the essential characteristics of plants and their functions, the improvement of the experimental group is approximately equal to that of the control group.

6 Conclusion

The goal of using augmented reality in education is to offer knowledge in a way that is more closely and directly related to what is happening around us (Ampartzaki et al., 2022; Bower et al., 2014). This research aimed to investigate the learning outcomes of the augmented reality application designed to teach the parts of plants and their functions included in the 7th unit of Environmental Studies in the 1st grade and to contribute to the more practical application of augmented reality applications in teaching practice (Karakose et al., 2023; Karakose et al., 2022).

Although in the overall score, the students of the experimental group improved to a greater extent than the students of the control group, there was no statistically significant difference between the experimental group and the control group. This means that the augmented reality application used in the experimental group did not significantly contribute to more excellent learning outcomes, even though its students responded better to the assessment sheet. While students in the experimental group gained a deeper understanding of the plant concept using augmented reality technology, students in the control group equally well-understood topics related to plant parts and functions. Therefore, the use of augmented reality technologies contributes to learning just as effectively as the traditional way of teaching (Yazıcı Arıcı et al., 2022; Mercan et al., 2022). Using AR apps will enhance the teaching of plants and their parts in the same way as conventional teaching (Papadakis et al., 2022). However, the limitations of the present research, such as the faint sound, the difficulty of using the tablet's buttons and the small sample of the present research, set the imperative need to plan and implement similar research in the future. Comparative studies, such as this one, help educators to identify practices that will make the teaching of plants and Environmental Studies courses more effective along with the simultaneous use of augmented reality technology.

Conflicts of interest

The author declares that they have no conflict of interest.

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