ATTITUDES OF FUTURE PRIMARY EDUCATION TEACHERS TOWARDS THE USE OF AUGMENTED REALITY MOBILE TECHNOLOGIES IN THE TEACHING OF HUMAN BIOLOGY

[a]MÁRIA FUCHSOVÁ, [b]LUCIA BUNDOVÁ, [c]RÓBERT OSAĎAN

Faculty of Education, Račianska 59, 813 34, Bratislava, Slovak Republic
email: [a]fuchsova@fedu.uniba.skl, [b]bundova@fedu.uniba.sk, [c]osadan@fedu.uniba.sk

This study was supported by grants KEGA 026UK-4/2022 Concept of constructionism and augmented reality in STEM education (CEPENSAR) and VEGA 1/0033/22 Inquiry-oriented teaching in mathematics, science, and technical education.

Abstract: Technological progress affects different areas of life, such as the economy, health or education, which inevitably requires experts from the given fields to adapt to the given changes. New technologies with modern teaching methods in education are often more motivating and attractive for students. In the following study, we evaluate the effectiveness of using one of such technologies, i.e. applications of augmented reality, in the teaching of human biology to university students, future teachers of primary education. We consider it important that new modern methods of teaching using modern technologies are part of the preparation of students for their future teaching profession. At the same time, we evaluate the attitudes of future teachers towards the use of modern technologies, as their appropriate implementation in teaching in primary education depends on their relationship to the given form of teaching. The conclusions of the study confirmed a higher understanding of the content of the university curriculum, better cooperation, as well as an increase in the interest and motivation of students. Despite the fact that the applications of augmented reality in the field of biology were known to students, they often did not use them to work with them. Students who graduated from biology, or graduated from gymnasium, were more familiar with the given teaching technology than students who did not graduate from high school in biology. The correct and appropriate implementation of modern technology in teaching is therefore also dependent on the students' previous knowledge and experience with the given topic of the subject in which modern technology can be used. Therefore, the introduction of modern technologies into the teaching of future teachers of primary education necessarily requires a sufficient understanding of the content of the subject in which the given technology will be implemented

Keywords: digital technology, augmented reality, human anatomy and physiology, student attitudes, biological knowledge and experience, teacher training

1 Introduction

Many authors have noted the positive impact of augmented reality in the context of education. Connecting virtual objects to the real environment allows students to visualize complex spatial relationships and abstract concepts (Arvanitis, et al., 2007). Various augmented reality technologies are therefore helpful in teaching complex and complicated subjects such as human anatomy (Ganguly, 2010). Fairén González, Farrés and Moyes Ardiaca emphasize that it is not possible to explain mainly the relationships between individual bodies organs common didactic aids such as textbooks and visual aids (Fairén González, Farrés, & Moyes Ardiaca, 2017). On the other hand, augmented reality applications in teaching anatomy provide students with interactive and convenient multimedia functions, thereby increasing students' interest in the subject (Kurniawan, Suharjito, & Witjaksonoa, 2018). Suzzana and Gaol (2021) add that the method of augmented reality also presents new prospects for adapting to different educational facilities, creating a unique educational approach capable of adapting to different types of students (Suzanna & Gaol, 2021).

At Ludwig-Maximilians-Universität (LMU) in Munich, the augmented reality method was used for the first time in the RGB-D sensor system in an anatomy course in the 2015/2016 school year. This system enables the connection of a real radiological image with the projection of the student's torso. Using gesture input, students have the opportunity to interactively explore radiological images in various cross-sections of anatomical structures. Kugelmann and his colleagues observed the reactions and opinions of students who had the opportunity to work with the system in groups of 12 members during the lesson (Kugelmann, et al., 2018). At the end of the research, each participant was invited to rate their satisfaction with work in the given system by filling out a questionnaire. Overall, the students evaluated the experience with the augmented reality system very positively and appreciated the use of this system within the anatomy course. The majority of students (69.1%) found the system useful. One of the main advantages of an augmented reality system compared to previously designed multimedia learning resources is its interactive component. 82.4% of students agreed that augmented reality stimulates active learning. In this case, the emphasis was mainly on active learning, but also on the three-dimensional understanding of individual body structures. As one of the most frequent advantages of the system, the students identified the improvement of the three-dimensional understanding of the structure by being able to switch and cut the virtual body in different planes (in the horizontal, sagittal and vertical directions) in the system. The authors were surprised that students found augmented reality technology more useful in understanding the three-dimensional display of structures compared to classic laboratory exercises. The shortcomings of the system were more of a technical nature. The most common disadvantages were the rapid failure of the augmented reality system and the lower graphical interface of higher resolution images. Alternatively, the students would welcome if the system were expanded to include additional images, and for more advanced students, the authors are considering the design of the system for pathological conditions as well. Research proves that for understanding the three-dimensional representation of anatomical structures, those applications that depict individual organ structures of the body at the same time and not just one organ part are suitable.

Although similar very well-designed interactive CDs for teaching anatomy are available today, a constant problem is their high cost. In contrast, augmented reality web applications are developed to support learning about the anatomy of the human body and are often available for free. The web interface is one of the media that is suitable for teaching support because it is easily accessible through computers, tablets and mobile phones which connect to the Internet. In addition, students already know how to handle devices, so they can quickly find their way around individual applications (Layona, Yulianto, & Tunardi, 2018). One such web application that displays the human body in a 4D environment is Anatomy 4D. In this application, all anatomical systems are displayed simultaneously and separately, thanks to which it reveals the spatial relationships of individual internal organs and allows students to understand the physiological processes that take place in the human organism. At the same time, it is possible to see very well in the application the explicit and detailed structure of the organs themselves. Based on the above facts, this simple learning environment is suitable for classroom teaching and is widely used mainly by teachers, students and practitioners. Through the application, teachers can visualize one of the most complex areas of biology, such as human anatomy (Anatomy 4D, 2019). In our research, we used the given application to explain the neurohumoral regulation of the child's growth and development, as this application provides a representation of individual organs within the human organism as a whole, thereby providing an explanation of the interrelationships of individual anatomical systems. We used the application The Brain iExplore for a detailed image of the brain (The Brain iExplore AR, 2019).

In the following study, we evaluate the effectiveness of the use of the two mentioned applications of augmented reality in the field of anatomy of the human body ("The Brain iExplore" and "Anatomy 4D") in the lesson of "Somatic development of the child" among students of the Faculty of Education of the Comenius University in Bratislava, future teachers at the primary level of education. In the study, we investigate whether more complex topics from the field of biology, such as neurohumoral regulation of growth and development, are more understandable using this teaching method and students are more motivated to learn the more demanding content of biology using the augmented reality method. Last but not least, we present in the study an evaluation of students' opinions on the use of mobile technologies (which cannot be used to work with

augmented reality applications) within higher education. The aim of the study was to evaluate the use of augmented reality applications and mobile technologies in the teaching of human biology. Furthermore, we evaluated the interest in the given type of teaching among students who completed the high school diploma in biology and who did not complete the high school diploma in biology, and at the same time we addressed whether the difference in the answers about interest can be influenced by the type of secondary school that the students attended before starting college. Vocational secondary schools often have fewer biology classes, or none compared to grammar schools, so the approach of students with different biology backgrounds to using apps may differ.

2 Material and Methods

Research focused on the use of augmented reality applications in the teaching of biology (within the subject Somatic development of the child) and the use of mobile technologies in the lives of university students was carried out in November 2017 in a group of 62 students (future teachers at the primary level of education) at the Faculty of Education of the Comenius University in Bratislava. The average age of the students was 19.73 years. We divided the students into two groups according to the type of secondary school the students attended (gymnasium (N = 32) or secondary vocational school - SVS (N = 30)) and according to whether they graduated from the subject of biology (N = 20) or did not graduate (N = 42). In the given lesson of repeating the subject of the child's somatic development, in which our research was carried out, we were also based on constructionist conceptions of learning. It should be recalled that the same students also completed the frontal organizational form of the Somatic Development of the Child lesson and at the same time a lesson with constructionist concepts of learning in a repeat lesson using mobile technology and augmented reality applications.

As part of the research, we used the following applications: "The Brain iExplore" and "Anatomy 4D". The card applications, needed to be loaded, are freely available on the Internet. The first application offers detailed color images of individual parts of the brain and the principle of the function of its motor area (figure 1).

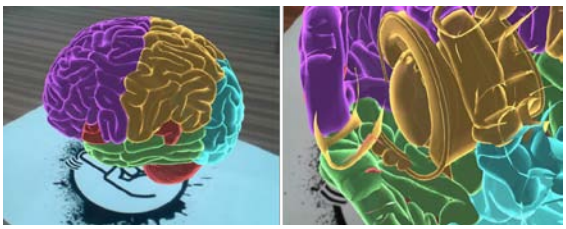

Figure 1. "The Brain iExplore" application: a color representation of individual parts of the brain visible on its surface using augmented reality (photo: Mária Fuchsová)

In the second application, the student can read the individual anatomical systems of the human body, simultaneously and separately (Fig. 2), for a better understanding of their connection and functioning within the framework of integration. Some functions of the human body are also described on the card, which serves as a marker for loading the application. As part of the neurohumoral regulation of growth and development, we used a card called "The Human Body".

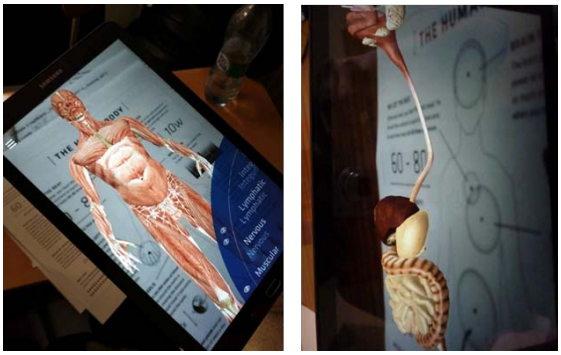

Figure 2. "Anatomy 4D" application: visualization of individual systems of the human body using augmented reality (photo: Mária Fuchsová)

During the revision lesson, students worked in groups of 3 to 4 people (17 groups) using the method of constructionist concepts. In the course of qualitative research, the results of which we present in the publication "Visualisation in Basic Science and Engineering Education of Future Primary School Teachers in Human Biology Education Using Augmented Reality" (Fuchsová & Koreňová, 2019), we observed the effect of augmented reality applications on student learning in constructionist environment. With "The Brain iExplore" and "Anatomy 4D" apps, students can use augmented reality technologies to study the anatomy of the nervous and endocrine systems as they appear in the apps in three dimensions. Students worked with the nervous and endocrine systems to understand the neurohumoral regulation of child growth and development. In the first activity, students had to identify parts of the brain in the application "The Brain iExplore" and describe their function, and in the second activity, students in the application "Anatomy 4D" had to identify endocrine glands in individual anatomical systems and describe their function. Each group received two cards needed to load the applications, one for "The Brain iExplore" application and one for the "Anatomy 4D" application. They worked with the given applications for 60 minutes. A particularly interesting part of the qualitative research was how the students tried to find those parts of the neurohumoral system on the Internet or in an anatomy book that were not familiar to them. Some students tried to translate the English names of anatomical systems into Slovak using the Internet. The results of the first part of our qualitative pedagogical research, published in the publication "Visualisation in Basic Science and Engineering Education of Future Primary School Teachers in Human Biology Education Using Augmented (Fuchsová & Koreňová, 2019), were based on the description of the teacher as an observer in the given research and on video recordings of students' work. Subsequently, we present the results of the second part of the research, which is based on the students' opinions on working with mobile technologies, as well as with the augmented reality applications themselves in the Somatic Development of the Child class. Students' interest in this type of teaching was verified by an electronic questionnaire. Each student filled out the questionnaire on his own. The questionnaire contained thirteen closed questions, one semi-closed and one open question. We compared the students' answers according to the type of high school they attended and whether they graduated with a high school diploma in biology. We present the differences in the answers of individual groups as a percentage. We tested the statistical significance in the differences of answers with the chi-square test (CHITEST) in the Excel program ($\alpha = 0.05$).

3 Results

The first task for the students in the lesson on repeating and understanding the neurohumoral regulation of child growth in the lesson of "Somatic development of the child" was to recognize the individual colored parts of the brain in the "The Brain iExplore" application, describe their function and identify which of these parts is most involved in growth regulation. Only five groups of students out of seventeen recognized all the parts

of the brain that the application depicts and correctly determined their function. It was interesting to see how these students, by approaching the model with their tablets, revealed the internal parts of the brain in the given application. The other students recognized only some parts, even one group of students could not recognize which part of the brain in the application is the front and which is the back (Fuchsová & Koreňová, 2019). The difficulty of the given task could result from the fact that the brain in the application as a whole moved in space and individual parts of the brain changed color at the same time. This also explains the fact that not all groups completed the activity for the given application. They tried to determine only the parts of the brain, but they did not determine their function. The answers to the first question from the questionnaire "Which application did you like the most?" also revealed a lesser interest in the given application, when the majority of students (regardless of whether they passed their high school diploma in biology or the type of school they attended) stated that they liked the work more with the "Anatomy 4D" application (87.5 to 96.67%, tab. 1).

According to Fuchsová and Koreňová (Fuchsová & Koreňová, 2019), it was the difficulty of the given task in the "The Brain iExplore" application that forced the students to cooperate more and they even did not hesitate to use other resources to complete the task (such as an anatomy book or a smartphone and the Internet). The authors of the study found that students often helped each other when solving the task. In most cases, they used the plural when talking to each other about the issue, which means that the students did not see their tasks as individual. The cooperation of the students was thus quite clear. During the lesson, students explored together, determined mutual connections and helped each other understand anatomical concepts and their functions. The students' mutual learning with the help of the constructionist approach was effective.

Table 1. Percentage display of answers to the question "Which application did you like the most“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
The Brain iExplore	2	10,00	3	7,14	4	12,50	1	3,33
Anatomy 4D	18	90,00	39	92,86	28	87,50	29	96,67

Note: CHITEST: the difference between the answers of students with and without a high school diploma in biology (p = 0.70), the difference between the answers of students who attended grammar school and SVS (p = 0,19)

In the second activity, students had to identify the endocrine glands in the individual anatomical systems of the "Anatomy 4D" application and describe which of them, through the hormones they secrete, are involved in the regulation of growth and development. The application offered English anatomical names. Some students took this as a challenge and started looking up individual terms on the Internet. On observation, it was very clear that the students worked together to solve the task; they explained some concepts and mutual relationships and performed activities without much intervention from the teacher (Fuchsová & Koreňová, 2019).

Working with the "Anatomy 4D" application was more interesting for the students and at the same time less demanding than working with the "The Brain iExplore" application (Table 1). In order to understand the individual anatomical structures, it is important to depict them in the organism as a whole. "The Brain iExplore" application contained only the structure of individual brain, which additionally moved in space and changed colors. As part of the "Anatomy 4D" application, students could view anatomical structures independently, but also as part of individual systems, which enabled students to better understand the interconnection of the relationships of the given systems, as well as their function in the regulation of the child's growth and development. We chose the application "The Brain iExplore" for work on the constructionist approach to learning because it showed more detailed brain structures than the "Anatomy 4D" application. We could therefore conclude that the most appropriate choice would be where the brain would be depicted in detail within the individual systems of the organism as a whole. This option is offered by other applications (e.g. Human Anatomy Atlas, 2024), which, however, unlike the selected applications ("The Brain iExplore" and "Anatomy 4D"), are only available on the Internet for a fee.

Despite the fact that the students worked better with the "Anatomy 4D" application in the revision lesson, the results of the questionnaire revealed to us that the students know both applications equally and even if they know them, they do not use them often (tab. 2 and 3).

Table 2. Percentage display of answers to the question "Do you know or use the application "The Brain iExplore "?“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Know and use	1	5,00	2	4,76	2	6,25	1	3,33
Know and do not use	16	80,00	30	71,43	25	78,13	21	70,00
Do not know	3	15,00	10	23,81	5	15,62	8	26,67

Note: CHITEST: the difference between the answers of students with and without a high school diploma in biology (p = 0.73), the difference between the answers of students who attended grammar school and SVS (p = 0,52)

Table 3. Percentage display of answers to the question "Do you know or use the application "Anatomy 4D"?“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Know and use	2	10,00	3	7,14	2	6,25	3	10,00
Know and do not use	16	80,00	30	71,43	25	78,13	21	70,00
Do not know	2	10,00	9	21,43	5	15,62	6	20,00

Note: CHITEST: the difference between the answers of students with and without a high school diploma in biology (p = 0,53), the difference between the answers of students who attended grammar school and SVS (p = 0,75)

From the given results, it also follows that students who graduated from biology, or graduated from grammar school, they know more about the augmented reality applications used ("The Brain iExplore" and "Anatomy 4D") than students who did not graduate from biology and only attended vocational high school. We did not notice statistically significant differences in the answers; this difference was only 9% (p > 0.05) (tables 2 and 3).

If we asked about other applications from the field of biology that students are familiar with, they were again more familiar with a higher percentage of students who graduated from biology (15.00% versus 2.38%) and attended gymnasium (9.38% versus 3. 33%, table 4). However, we did not see a statistical difference in the responses (p > 0.05) and when we looked at the type of applications that the students mentioned, we learned that the applications in question were not from the field of augmented reality. The students mentioned "Human Body" app which is a virtual reality app, "Kahoot" app which is just a mobile app without virtual or augmented reality. The only app that featured augmented reality was the “Human anatomy” app, which was mentioned by only one student.

Table 4. Percentage display of answers to the question "Do you know or use other applications for biology?“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Yes	3	15,00	1	2,38	3	9,38	1	3,33
No	17	85,00	41	97,62	29	90,62	29	96,67

Note: CHITEST: the difference between the answers of students with and without a high school diploma in biology (p = 0,06), the difference between the answers of students who attended grammar school and SVS (p = 0,33)

It is clear from the students' answers that the repeat lesson of the subject "Somatic development of the child" with the use of augmented reality applications was interesting for the students (tab. 5) and despite the fact that most of them had not encountered this type of teaching until now, all except one students agreed with the opinion that they would welcome this type of teaching in biology classes in the future as well (tab. 6).

Table 5. Percentage display of answers to the question "Were you interested in the activity with augmented reality in the lesson "Somatic development of the child“?“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Yes	19	95,00	39	92,86	31	96,88	27	90,00
No	1	5,00	3	7,14	1	3,12	3	10,00

Note: CHITEST: the difference between the answers of students with and without a high school diploma in biology (p = 0,75), the difference between the answers of students who attended grammar school and SVS (p = 0,27)

Table 6. Percentage display of responses to the question "Do you think the biology class would be more interesting using the given augmented reality applications?“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Yes	20	100,00	41	97,62	32	100,00	29	96,67
No	0	0,00	1	2,38	0	0,00	1	3,33

Note: CHITEST: the difference between the answers of students with and without a high school diploma in biology (p = 0,49), the difference between the answers of students who attended grammar school and SVS (p = 0,30)

At the same time, the applications of augmented reality models that we used in the lesson "Somatic development of the child" ("The Brain iExplore" and "Anatomy 4D") helped the students to better understand the neurohumoral regulation of growth and development of the child (tab. 7). In fact, more than 80% of students (regardless of whether they graduated from biology or the type of school they attended) stated that they gained new information about the subject through the given activity with augmented reality (tab. 8).

Table 7. Percentage display of answers to the question "Did the activities with AR model applications help you when repeating the given biology lesson?

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Yes	19	95,00	40	95,24	29	90,62	30	100,00
No	1	5,00	2	4,76	3	9,38	0	0,00

Note: CHITEST: the difference between the answers of students with and without a high school diploma in biology (p = 0,97), the difference between the answers of students who attended grammar school and SVS (p = 0,09)

Table 8. Percentage display of answers to the question "Did you gain any new information about the given issue with the given activity with augmented reality?“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Yes	16	80,00	36	85,71	27	84,38	25	83,33
No	4	20,00	6	14,29	5	15,62	5	16,67

Note: CHITEST: the difference between the answers of students with and without a high school diploma in biology (p = 0,57 the difference between the answers of students who attended grammar school and SVS (p = 0,91)

At the end of our research, we were interested in how students perceive the possibility of using mobile technologies (smartphones and tablets, which can also be used to visualize augmented reality applications) in the teaching of biology in higher education. Students who did not graduate from the subject of biology and attended secondary vocational school considered the use of mobile technologies very useful in teaching biology, while students who graduated from biology, or attended grammar school more often stated that the use of mobile technologies is only somewhat useful in teaching biology. In the group of students according to the type of secondary school they attended, there were even differences in the answer on the border of statistical significance (p = 0.05, tab. 9). Perhaps the fact that most high school students had little knowledge of biology plays a bigger role here, and therefore the easier form of transferring biological information using augmented reality seemed more engaging and interesting to them.

Table 9. Percentage display of answers to the question "Do you think mobile technologies are useful in teaching biology?“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Very useful	10	50,00	29	69,05	16	50,00	23	76,67
Somewhat useful	8	40,00	12	28,57	13	40,62	7	23,33
I do not know	2	10,00	1	2,38	3	9,38	0	0,00

Note: CHITEST: the difference between the answers of students with and without a high school diploma in biology (p = 0,2357 the difference between the answers of students who attended grammar school and SVS (p = 0,05)

The students answered the same way in the case of the question of the effectiveness of using smartphones and tablets in teaching biology, even though the percentage differences in the answers were smaller in this case without statistical significance between both groups. Only 75% of students who had final exam from

biology considered teaching biology using smartphones and tablets to be effective, compared to 90.48% of students who did not have final exam from biology. In the group of students from different types of schools they attended, there was only a 2.3% difference in the answer (tab. 10).

Table 10. Percentage display of answers to the question "In your opinion, it would be effective if students used smartphones or tablets more in biology lessons?“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Yes	15	75,00	38	90,48	27	84,37	26	86,67
No	4	20,00	2	4,76	3	9,38	3	10,00
I do not know	1	5,00	2	4,76	2	6,25	1	3,33

Note: CHITEST the difference between the answers of students with and without a high school diploma in biology (p = 0,16), 57 the difference between the answers of students who attended grammar school and SVS (p = 0,87)

An open question in the questionnaire encouraged students to express their opinion about the use of augmented reality applications and the use of mobile technologies in teaching biology. Students who graduated from the subject of biology, or they attended gymnasium, they considered the given type of teaching to be very interesting. They literally claimed that working with the given applications provided "a very interesting execution within the 3D model, an excellent understanding of the placement of individual organs" and that "it would be appropriate to devote more time to it in the class", but they saw the possibility of connecting to the Internet as the main problem. They stated that "the apps took a long time to load and freezed" and that "it would be better if the apps worked without internet". The students, graduates of secondary vocational schools, also enjoyed working with augmented reality models, but they had a question about the English version of the given applications. They would like to welcome applications in the Slovak language. More often, they considered working with applications to be more demanding, and they also noted malfunctions with devices, tablets, with the help of which it is possible to work with applications. It should be emphasized that the functioning of augmented reality applications, which we used in the revision class, as well as other applications with augmented reality, is often dependent on the Internet connection, which means that it also depends on the material and technological support of the faculty.

Despite the minor shortcomings in connection to the Internet, we see the use of mobile technologies in the teaching of biology as very promising, because the students of today's generation own mobile technology (tab. 11), they can easily install the applications of augmented reality which are freely available on the Internet to their devices (especially smartphones) and use them in class using a mobile internet connection.

Table 11. Percentage display of answers to the question "What mobile technology do you own?“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Smartphone	19	95,00	41	97,62	31	96,88	29	96,67
Laptop	20	100,00	37	88,10	31	96,88	26	86,67
Tablet	4	20.00	15	35,71	6	18,75	13	43,33
Book reader	0	0,00	2	4,76	0	0,00	2	6,67
Apple watch	0	0,00	1	2,38	0	0,00	1	3,33

Note: CHITEST: the difference between the answers of students with and without a high school diploma in biology (p = 0,61), 57 the difference between the answers of students who attended grammar school and SVS (p = 0,20)

Table 12. Percentage display of answers to the question "Do you have a mobile internet connection?“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Yes	18	90,00	38	90,48	28	87,50	28	93,33
No	2	10,00	4	9,52	4	12,50	2	6,67

Note: CHITEST the difference between the answers of students with and without a high school diploma in biology (p = 0,95), 57 the difference between the answers of students who attended grammar school and SVS (p = 0,44)

More than 87.5% of students have a mobile internet connection (tab. 12), but a smaller percentage uses a wifi connection provided by the faculty (73.33% - 81.25%, tab. 13). As the students already stated in the free question, they see the main problem in using augmented reality applications in the biology lesson mainly in connection to the Internet. After improving the material and technological provision of the faculty, the use of this form of teaching biology can be very interesting and stimulating for students, as they stated that working with applications is fun for them, motivating them to learn complex topics in the field of biology and at the same time providing them better understanding of the subject matter.

Table 13. Percentage display of answers to the question "Do you use a wifi connection provided by the faculty?“

	With diploma in biology		Without diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Yes	16	80,00	32	76,19	26	81,25	22	73,33
No	4	20,00	10	23,81	6	18,75	8	26,67

Note: CHITEST: the difference between the answers of students with and without a high school diploma in biology (p = 0,74), 57 the difference between the answers of students who attended grammar school and SVS (p = 0,46)

We recommend to use more mobile technologies and applications of augmented reality in teaching biology at the university, as already more than 80% of students use technology in learning (tab. 14), so it is obvious that this type of obtaining information about the given issue is familiar and close to them. From the conclusions of the research, we can confirm that by using the form of teaching with the help of augmented reality, it is possible to achieve an increase in students' interest in more complex topics in the field of biology, such as neurohumoral regulation of child growth and development.

Table 14. Percentage display of answers to the question "Do you use a smartphone/tablet as part of learning?“

	With diploma in biology		ithout diploma in biology		Grammar school		SVS	
	N	%	N	%	N	%	N	%
Yes	18	90,00	34	80,95	28	87,50	24	80,00
No	2	10,00	8	19,05	4	12,50	6	20,00

Note: CHITEST the difference between the answers of students with and without a high school diploma in biology (p = 0,37), 57 the difference between the answers of students who attended grammar school and SVS (p = 0,42)

4 Discussion

With the use of augmented reality applications that mobile devices bring to education, students should be able to improve their learning environment and their ability to retain information. The conclusions of our qualitative study confirmed that augmented reality mobile technology helps students to understand better the content of biology from the field of human anatomy and physiology. It seems that the teaching method using augmented reality technology is effective. Students moved from regular instructional learning to the method of independent education and mutual learning (Fuchsová & Koreňová, 2019). Augmented reality applications are mainly suitable for students who have a problem with converting and visualizing a two-dimensional shape into a three-dimensional real image (Layona, Yulianto, & Tunardi, 2018). Medical and biology teachers point out that the use of augmented reality can help identify anatomical structures, strengthen the association between anatomy, physiology and movement through their use on mobile devices (Siqueira da Silva, Klein, & Munchen Brandão, 2017).

Despite the fact that nowadays various information technology means are often used in education, augmented reality technology has not been sufficiently accepted (Azuma, Billinghurst, & Klinker, 2011). According to Billinghurst, this technology is still underutilized because there are not enough experts available who are able to expertly fulfill the content of the subject (Billinghurst, 2024). But if we look at the opinion of the teachers themselves about the given applications, the teachers, despite the fact that they have no previous experience with the given form of teaching, accept the new technology positively. They are able to orient themselves in the given applications very quickly (Iftene & Trandabăț, 2018) and consider augmented reality applications to be simple and useful (Yilmaz, 2016). The ease of use of augmented reality applications was also confirmed by the results of our quantitative research, when students who had lower knowledge and abilities in biological content considered this form of teaching more attractive and useful in teaching complex structures of the human body.

Another issue of the introduction of augmented reality technologies into the teaching process is the lack of material and technological support of universities. For example, Lin and colleagues reported that students find augmented reality applications as complicated and often encounter technical difficulties (Lin, Hsieh, Wang, Sie, & Chang, 2011). During our research, we noticed problems with the Internet connection, which made it impossible to work with some augmented reality applications, which reduces the effectiveness of using tablets and augmented reality applications in teaching biology. Moreover, without a well-designed interface and student guidance, augmented reality technology as a teaching method can be too complicated (Squire & Jan, 2007). The students of our study saw the ability to connect to the Internet as the main problem in using augmented reality applications. They stated that "the apps took a long time to load and freezed" and that "it would be better if the apps worked without internet". Iftene and Trandabăț who have used apps to teach biology to school-age students, add that younger students tend to tap the screen too quickly, which can often block apps (Iftene & Trandabăț, 2018).

However, most studies report that augmented reality technology leads to improved learning outcomes at all levels of education. Augmented reality applications increase the motivation to learn and at the same time help students to better understand the content of the curriculum of the given subjects (Akçayır & Akçayır, 2017). However, it is also necessary to take into account the age of the recipients of the given technologies, as improperly implemented interactions with the form of augmented reality can lead to passivity (Yilmaz, 2016). In his studies, Yilmaz brings augmented reality technology closer to children in the form of toys (puzzles and cards). In this form, children of preschool age accepted augmented reality applications positively. The applications interested them, they were involved in the activity and were active in education. The author then reminds that the implementation of augmented reality in the form of games, stories and puzzles played an important role in the adoption of applications by children. Iftene and Trandabăț noted interest in augmented reality applications even among students of aged 9 to 16, if this teaching method was introduced to them in the form of a competition (Iftene & Trandabăț, 2018). All the mentioned authors say that it is very fun for children, as well as pupils, to observe objects in 3D real space. The attractiveness of the given applications also depends on the quality and method of implementation of augmented reality objects. Students who participated in our research confirmed that working with the "Anatomy 4D" application was more interesting and less demanding for them than working with the "The Brain iExplore" application. In order to understand the individual anatomical structures, it is important to visualize them in the organism as a whole, which the application "The Brain iExplore" did not fulfill. The given application only provided an image of the given structure of the brain, as a separate unit and not as a part of the organism. In addition, the given structure moved and changed colors in the application. Kugelmann and colleagues, who used augmented reality in the form of X-ray images and detailed depictions of body structures within the organism, even found that students in anatomy classes found the technology more useful in depicting three-dimensional structures than classic laboratory exercises (Kugelmann, et al., 2018). However, Kiourexidou and the team emphasize that this method does not serve as a substitute for laboratory exercises, but rather serves as a complementary method to continuous education in an environment outside of school (Kiourexidou, et al., 2015). Therefore, before incorporating augmented reality applications into the teaching process, it is advisable to analyze its suitability for the given content of the teaching subject adapted to the age of the pupils or students.

In general, educational technology researchers agree that augmented reality technology, as one of the teaching methods, should be more thoroughly and researched (Lee, et al., 2012). The use of this technology could be very effective in motivating students, as well as in supporting the active involvement of students in the teaching process. Based on the results of our study, we encourage schools at all levels of education to adopt and implement augmented reality applications as an effective tool for positive learning and education.

5 Summary

In the present study, we investigated how augmented reality technology can contribute to a better understanding of human anatomy curriculum. Subsequently, we summarized the opinions of university students on the use of augmented reality technology in the teaching of biology, specifically human anatomy and physiology. This research followed the previous research by the authors Fuchsová and Koreňová (2019), which conclusions confirmed a higher understanding of the content of the university curriculum, better cooperation, as well as an increase in the interest and motivation of students. Augmented reality applications in the field of biology, which were the subject of research, were known to the students, but they did not use them to work with them. Students who graduated from

biology, or graduated from grammr school, were more familiar with the given teaching technology than students who did not graduate from high school in biology. These students also mentioned other well-known mobile apps, but the apps they mentioned did not include augmented reality technology. The class using augmented reality applications was interesting for the students, and despite the fact that most of them had not encountered this type of teaching until now, all except one student agreed that they would accept this type of teaching in biology classes in the future. Students considered the use of mobile technologies in the teaching of biology in higher education to be very useful and effective, while students from secondary schools without a biology degree support more this opinion. The results could probably be influenced by the fact that the majority of secondary school students had less knowledge of biology and therefore an easier form of transfer of biological information from human anatomy and physiology seemed more engaging and interesting to them. The only disadvantage in the use of augmented reality applications is that they are tied to an Internet connection. Due to the lower material and technological provision of the faculty, work with augmented reality technologies can therefore be difficult and more complicated. The advantage of freely available augmented reality applications is that they are inexpensive, but it is necessary to take into account that they are often modified by developers and that updated versions or new ones are created, the functionality of which can be used for the given educational content should be analyzed in advance.

Despite minor shortcomings in the use of applications, we consider augmented reality technology to be a suitable method of teaching biology and recommend its inclusion in the educational process as a complementary method to classical educational methods. Our results are encouraging and we are convinced that such new technologies, if regularly used in biology teaching, can be an important tool of a modern and integrated educational program.

Literature:

1. Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. Educational Research Review 20, 1-11.
2. Anatomy 4D. (2019, April 4). Retrieved from https://anatomy-4d.en.uptodown.com/android/download, marker: http://getrealscience.org/tzhao/2015/11/28/a-magic-application-anatomy-4d/.
3. Arvanitis, T. N., Petrou, A., Knight, J. F., Savas, S., Sotiriou, S., & Gargalakos, M. (2007). Human factors and qualitative pedagogical evaluation of a mobile augmented reality system for science education used by learners with physical disabilities. Personal and Ubiquitous Computing, 13(3), 243-250.
4. Azuma, R., Billinghurst, M., & Klinker, G. (2011). Special Section on Mobile Augmented Reality. Computers & Graphics, 35.
5. Billinghurst, M. (2024, February 9). Augmented Reality in Education. Retrieved from http://www.solomonalexis.com/downloads/ar_edu.pdf.
6. Fairén González, M., Farrés, M., & Moyes Ardiaca, J. (2017). Virtual Reality to teach anatomy. Eurographics: education papers, 51-58.
7. Fuchsová, M., Koreňová, L. (2019). Visualisation in Basic Science and Engineering Education of Future Primary School Teachers in Human Biology Education Using Augmented Reality. European Journal of Contemporary Education, 8(1), 92 - 102.
8. Ganguly, P. K. (2010). Teaching and Learning of Anatomy in the 21 Century: Direction and the Strategies. The Open Medical Education Journal, 3, 5-10.
9. Human Anatomy Atlas. (2024, February 9). Retrieved from https://www.visiblebody.com/anatomy-and-physiology-apps/human-anatomy-atlas.
10. Iftene, A., & Trandabăţ, D. (2018). Enhancing the Attractiveness of Learning through Augmented Reality. Procedia Computer Science, 126, 166–175.
11. Kiourexidou, M., Natsis, K., Bamidis, P., Antonopoulos, N., Papathanasiou, E., Sgantzos, M., & Veglis, A. (2015). Augmented reality for the study of human heart anatomy. International Journal of Electronics Communication and Computer Engineering. 6(6), 658.
12. Kugelmann, D., Stratmann, L., Nühlen, N., Bork, F., Hoffmann, S., Samarbarksh, G., Waschke, J. (2018). An Augmented Reality magic mirror as additive teaching device for gross anatomy. Annals of Anatomy, 215, 71–77.
13. Kurniawan, M. H., Suharjito, D., & Witjaksonoa, G. (2018). Human Anatomy Learning Systems Using Augmented Reality on Mobile Application. Procedia Computer Science, 135, 80–88.
14. Layona, R., Yulianto, B., & Tunardi, Y. (2018). Web based Augmented Reality for Human Body Anatomy Learning. Procedia Computer Science, 135, 457–464.
15. Lee, J. R., Jung, Y. J., Park, S. R., Yu, J., Jin, D. S., & Cho, K. (2012). A Ubiquitous Smart Learning Platform for the 21st Smart Learners. Advanced Science and Engineering Education, 733-738.
16. Lin, H.-C. K., Hsieh, M. C., Wang, C. H., Sie, Z. Y., & Chang, S. H. (2011). Establishment and usability evaluation of an interactive AR learning system on conservation of fish. The Turkish Online Journal of Educational Technology, 10(4), 181-187.
17. Siqueira da Silva, I. C., Klein, G., & Munchen Brandão, D. (2017). Segmented and Detailed Visualization of Anatomical Structures based on Augmented Reality for Health Education and Knowledge Discovery. Advances in Science, Technology and Engineering Systems Journal, 2(3), 469-478.
18. Squire, K. D., & Jan, M. (2007). Mad City Mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. Journal of Science Education and Technology, 16(1), 5-29.
19. Suzanna, S., & Gaol, F. L. (2021). Immersive learning by implementing augmented reality: Now and the future. Journal of Computer Science and Visual Communication Design, 6(1), 22-28.
20. The Brain iExplore AR. (2019, April 4). Retrieved from https://play.google.com/store/apps/details?id=com.carltonbooks.iexplorethebrain&hl=en_US.
21. Yilmaz, R. M. (2016). Educational magic toys developed with augmented reality technology for early childhood education. Computers in Human Behavior, 54, 240-248.

Primary Paper Section: A

Secondary Paper Section: AM