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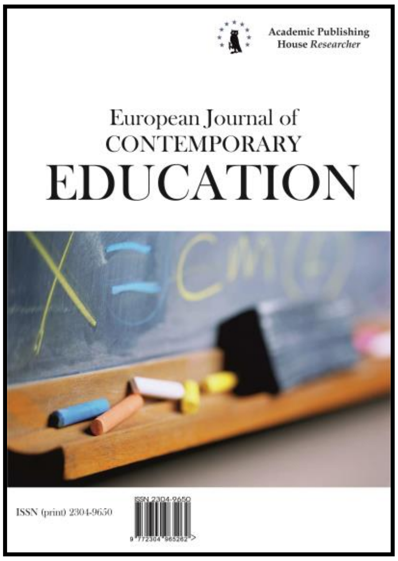

Visualisation in Basic Science and Engineering Education of Future Primary School Teachers in Human Biology Education Using Augmented Reality

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Abstract

New technologies with a modern method of teaching must be implemented in university studies, and an important part is teacher training study. These technologies make study more attractive for students and bring greater motivation to an understanding of notions. The main focus of this study is visualisation in science and engineering education using augmented reality in the context of biology education based on constructivist and constructionist concepts. We present in our contribution augmented reality technology as a part of using mobile technologies in biology education for future primary school teachers. The study is focused on perception of this method by future primary teachers who will teach biology as one of the areas of primary education and who were also the subjects of the research. We also mention two already existing biology-themed augmented reality applications, which appear to be interesting, enhancing and beneficial in the context of biology education. The findings of the study confirmed, using this method, that the students' understanding was deeper, their motivation was greater, and, last but not least, their creativity was strongly supported. The students were motivated by the new method, they cooperated very well and learning was constructive.

Keywords: visualisation, augmented reality, constructivism, constructionism, anatomy, digital technology, teacher training, pre-service teachers, primary level of education.

1. Introduction

The technological and social changes related to using mobile devices brings the question, how is it possible to implement these technologies into the educational process? Typical examples of the devices used for mobile learning include cell phones, smartphones, palmtops, and handheld computers; tablet PCs, laptops, and personal media players can also fall within this scope (Ferko, Koreňová, 2015). Sharples (2009) presented different views of defining mobile learning. Current perspectives on mobile learning generally fall into the following four broad categories:

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1. Technocentric. This perspective dominates the literature. Here, mobile learning is viewed as learning using a mobile device, such as a PDA, mobile phone, iPod, PlayStation Portable, etc.;
2. Relationship to e-learning. This perspective characterises mobile learning as an extension of e-learning;
3. Learner-centred;
4. Augmenting formal education.

Using mobile technology and the subsequent visualisation of abstract concepts, we can make it easier for students to zoom in and demonstrate the subject matter of complex subjects. At present, students meet with visualisation every day in the form of visual TV images and video games. In contrast, the standard form of teaching is passive and is not exciting for them. But through the simple technique of visualisation, we can transform students from passive learners to active teachers. Visualisation can help students improve their understanding of the subject's curriculum (Puett Miller, 2004). One of the methods of mobile learning that allow us to demonstrate the visualisation of a given subject is Augmented Reality.

The term Augmented Reality (AR) was created around the year 1990 and it presents virtual images in the real world, i.e., the reality is augmented of virtual elements. The integration of such images is made by the use of Information and Communication Technologies (ICT), through a mobile device with a camera (tablet or mobile phone with android system), which provides access to the environment of AR. Further, the development of AR content encourages higher learning autonomy and supports mobile-learning. Besides, the exploration of ICT by students can promote collaboration, innovation and creativity skills (Coimbra et al., 2015). Augmented reality is the supplementation of the reality perceived by the user with virtual elements. The use of mobile AR technology applications allows the work of educators to be made more effective, and in addition, it enables pupils to become actively involved in the education process (Azuma et al., 2001; Gunčaga, Janiga, 2016; Krawczyk-Stańdo et al., 2013).

AR technology helps the student to gain improved access to the subject because it mobilises the learning environment and allows learning flexibility. In addition, AR technology features support students in learning complex subjects in general; in particular, the subject of human anatomy as one part of biology education. Human anatomy involves learning anatomy in the practical dissection laboratory, with exposure to the structure of the human body and internal organs (Farlex, 2014). The practical session facilitates students to learn more complex parts of the body structure. Nevertheless, after the practical sessions, most students have difficulty repeating the information from this subject. Ganguly (2010) states that human anatomy didactic lectures followed by practical dissections could not generate long-lasting understanding of the subject, while AR applications had a positive impact on students' understanding of the content, as well as memory retention. When speaking about AR application in more detail, the visualisation of the internal structures may serve as a stronger memory trigger for students (Radu, 2014).

AR visualisations not only eventually improve students' knowledge of the subject of human anatomy, but also improve clinical skills in the laboratory (Garrett et al., 2015). Garrett and et al. (2015) found that students' knowledge acquisition, self-directed learning, and laboratory skills improved by using AR technology. Carlson and Gagnon (2016) similarly describe the use of AR technologies to improve clinical skills. They use the ARISE (Augmented Reality Integrated Simulation Education) system, which enables virtual clinical scenes to be set up for students to diagnose virtual patients. It is a system used in the education of medical students. The ARISE system is an innovative way to enhance simulation in learning clinical skills, provide authentic interactions, and potentially assist learning (Carlson, Gagnon, 2016).

One of the applications focused on the human body (male and female) is **Anatomy 4D,** which enables students to experience the interactive 4D environment of human anatomy. In this application, it is possible to view all the systems simultaneously and separately. It reveals the spatial relationships of the individual internal organs and enables students to understand the physiological processes that arise between and within individual organs. It is also very good to see the detailed structure of the organs themselves. Based on the abovementioned facts, this simple learning environment is good for use in the classroom and is widely used by teachers, students, medical professionals, and medical practitioners. Through this application, biology tutors can visualise one of the most complex systems, human anatomy (Anatomy 4D, 2018).

Further to the application that explores human anatomy in general, we will now consider an application that focuses just on parts of the human body. The **Brain iExplore AR** application provides detailed information about the brain. This AR application shows how the brain reacts to sounds, as well as the upside-down images of the world that the eyes actually see before the visual cortex of the brain processes them. Through this application, it is possible test fine motor skills and find what part of the brain deals with short-term memory in the matching pairs game (The Brain iExplore AR, 2018). The environments of both AR applications we used in our study are illustrated in Figure 1.

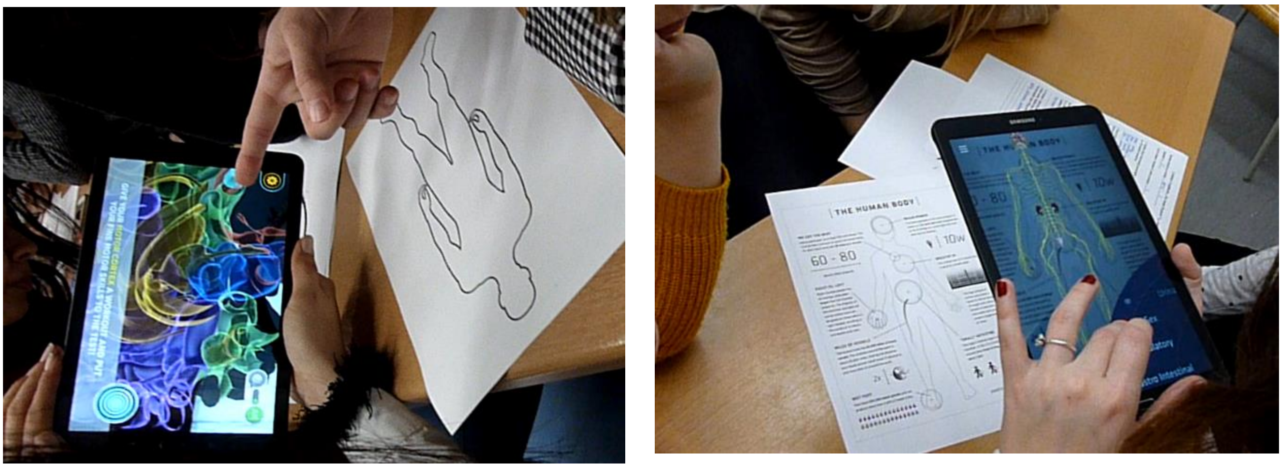

Fig. 1. Students represent the anatomical parts of the neural and endocrine system with the augmented application "The Brain iExplore" and "Anatomy 4D"

It is extremely motivating for students if we make fields more comprehensible for them with the aid of augmented reality, as some can be difficult to understand, such as the anatomy and physiology of neural and endocrine system. These applications are free of charge and the markers can be also printed free of charge. They work in a similar way as the AR Flashcard Shapes, which is good for increasing users' motivation.

The inductive (constructivist) approach in teaching, compared to a deductive approach, is characterised by distinctly different characteristics (Kostrub, 2008, 2016, 2017a, 2017b). The constructivist theory of learning assumes that each person creates himself, and constructs his own knowledge of the world in which he lives. Constructivism tries to overcome the transmissiveness of traditional teaching – the transfer of "teachers'" knowledge to the students. It deals with learning and understanding (Stoffová, Štrbo, 2016; Tóthová et al., 2017).

An increasing number of researchers have come to the following view: the knowledge is essentially "situated" and is not detached from the situations in which it is constructed and actualised. This growing interest in the idea of situated knowledge, or knowledge as it lives and grows in context, has led many researchers to look closely at individual people's ways of knowing, or relating. Constructionism is an educational theory that has many applications in the digital school environment (Kostrub, Severini, 2017; Sabelli, 2008**Ошибка! Источник ссылки не найден.**).

The root for constructionism was constructivism. Constructivist instructional design, according Kalaš (2013), aims to provide generative mental constructions embedded in relevant learning environments that facilitate knowledge construction by learners. The constructivist approach has many applications in different areas (Kalaš, Winczer, 2008). In the following research, we used these pedagogical theories, because students – pre-service teachers for primary level work with different applications used augmented reality. These applications were tools for a better understanding of the base anatomical notions.

2. Materials and Methods

We conducted the research in a group of 61 students in their first year of the bachelor study in the teacher training program for future teachers in primary level. The pedagogical experiment was realised in November 2017 at the Faculty of Education at Comenius University in Bratislava.

Our research focused on analysing the use of mobile technology and manipulation activities in teaching biology based on constructivist and constructionist concepts. We looked into the problem of how to incorporate the use of tablets in education. We believe that using this method, the students' understanding is deeper, their motivation is greater, and, last but not least, their creativity is strongly supported. The AR applications "The Brain iExplore" and "Anatomy 4D" were installed with cards on tablets (Figure 2).

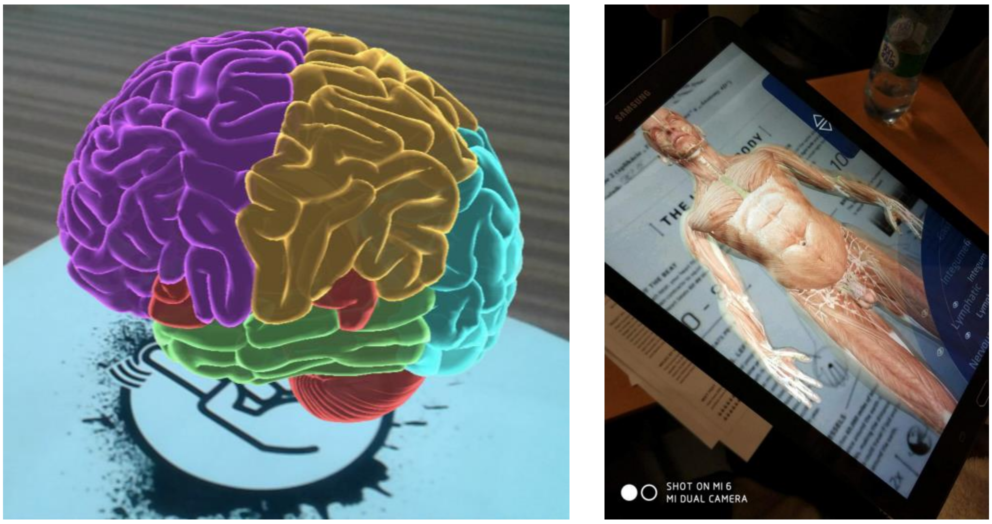

Fig. 2. Applications "The Brain iExplore" and "Anatomy 4D"

Some students used the books of anatomy and smartphones (internet) for solving the tasks (Figure 3).

Fig. 3. Student working with book of anatomy and with smartphones

Students worked in groups of 3 or 4 persons (17 groups) during the lesson, using the constructive method. In the course of the qualitative research, we researched to observe the effect of the AR applications "The Brain iExplore" and "Anatomy 4D" on learning in a constructivist environment. Using these applications on the tablet, they can use AR to study the anatomy of neural and endocrine systems that appear in three dimensions. The students worked with neural and endocrine systems to understand neurohumoral regulation of growth and development during the lesson of "somatic child development". The task for the students was to identify parts of the brain in the "Brain iExplore" application and to describe their function, and in the application "Anatomy 4D" to identify endocrine glands in individual anatomical systems. Every group obtained two cards, one for the “Brain iExplore” application and one for the “Anatomy 4D” application. They worked for 60 minutes. A particularly interesting part of the research was to see how students tried to find those parts of the neurohumoral system on the internet or in the anatomy book, which were unknown to them. Some students tried to translate the English names of anatomy systems to Slovak on the internet. At the end of the lesson, students submitted a protocol (one for each group).

Our qualitative pedagogical research relies on the description of the teacher's observations and on the video recording of the students’ work. The interest of students in this type of teaching method was verified by an electronic questionnaire. Each student completed a questionnaire. The questionnaire contained 10 closed questions. The first six questions in the questionnaire revealed the real interest of the students in the applications of augmented reality in the biology lesson, and whether this form of teaching helped them to better memorise anatomy information. The other four questions focused on the students’ view of using smartphones and tablets during the biology lesson, because augmented reality applications can only by these technologies. For nine questions, students were given one choice of answer. Only in question number 8, "How do you use a smartphone/tablet while you study?", can students choose more answers. All answers to the questions were evaluated in percentages.

3. Results

Through the use of the open coding method and video-recording transcription, we defined three categories and their sub-categories, which are summarised in the following table:

Table 1. Categories of students’ activities

CATEGORY	SUBCATEGORY	EXPRESSIONS AND ACTIVITIES
1. Students´ mutual learning – constructionist approach	1. Students support each other	We could determine it; We will see how it can be done...; We will try it this way; We need to find out what it is; We should try it; We solved it
	2. Mutual learning helps them to understand terms and relations	You have to come and see; You can set up your tablet so we can see it; I do not understand it, and can you explain it to me?; You will not see these parts of the brain on the tablet, because...; Try to give something else to compare it
	3. They do not collaborate with each other	I think...; I will overwrite it; I do not see anything there
2. Influence of mobile technology	1. Mobile technology helps them understand human anatomy	There is an emphasis on the whole body; The middle brain is the smallest; This purple and yellow part has two hemispheres; There are no pathways of the nervous system; It will be the whole brain stem; We found the pancreas in the digestive system
	2. Thanks to mobile technology, they recognise the different nomenclature of anatomical parts	Do you know how to say it in Slovak?; Do you know how to say it in English?; Pons is the bridge; Cerebellum is the brain; The pituitary gland is “hypophysis”; Skeletal is the skeleton
	3. It helps them when they can make several attempts thanks to the technology	I have several attempts, several solutions; I can correct myself; Try it differently
3. Manipulation	1. Improving	When you set up a tablet like this, you see...; Look

activities	manipulation ability by mobile technology	at it from the side; Try to go closer to see...; Try to zoom it; Something click there; The “eye” means we see them; Here you can choose something; Are you looking at the internet?
	2. Students are more motivated	It would be interesting if...; I fall off, it is good; Try it too; We solved it; We are wise; I already understand it now
	3. Disinterest of mobile technology	That's weird; That's disgusting; That's awful; It is not working; I do not know; It does not matter

The defined categories referred to constructionist teaching and the students’ manipulation activities. Constructionist teaching takes place through didactically considered but conceptually open teaching activities, and through discourse (controlled argumentation, handling facts) in the form of individual as well as group exploration (learning groups), thanks to which common knowledge and understanding is established. The categories we defined were given names expressing the best given group of related expressions. Having grouped and identified data in this way, we tried to understand and evaluate them from our perspective.

The first task of the students was to recognise the colour of anatomical parts of the brain in the "Brain iExplore" application. Students recognised only a few parts of the brain through AR. Only five groups correctly recognised all the parts of the brain that the app offered. One group had the problem of determining which part of the brain is front and back. It was interesting when some students revealed some inner parts of the brain in the application. In this application, the brain was moving, changing colours, and the work with this application was therefore more challenging for students. A smaller interest in this app has also confirmed the question, "Which application did you like more?" The application "Anatomy 4D" was liked by 91.8 % of students. The application "Brain iExplore" was liked by 8.2 % of students (Table 2).

Table 2. Answers to question 1

Which application was more interesting for you?		
The Brain iExplore	5	8.2%
Anatomy 4D	56	91.8%

Some groups had almost no interest in completing the role, which contained the question about function of the individual parts of the brain. However, especially when completing this task, students collaborated most and did not hesitate to use other sources to fill the task (anatomy book or smartphone, internet). Through the transcription of the video-recordings and structured observations, we found that the students frequently helped each other. In most cases, they used the plural form when they talked to each other, which means that the students did not consider their tasks to be individual (Table 1, category no. 1, subcategory no. 1). This exercise was a repetition of the curriculum at the end of the semester in terms of the understanding of neurohumoral regulation of growth and development. We were surprised when students did not want to fill the task. 83.6 % of students admitted that they received new information through mobile technology (Table 3). Finally, it is worth noting that up to 95.1 % of students recognised that mobile technology helped them to repeat the lesson and helped them understand human anatomy (Table 4 and 5). Table 1 (category no. 1, subcategory no. 2) shows the cooperation of the students was quite clear. During the classes, they explored together, they determined interconnections and helped each other with understanding the topic. The constructivist environment established by us significantly helped the students in their work and students’ mutual teaching with the help of a constructivist and constructionist approach.

Table 3. Answers to question 2

Did you find new information about the issue by using augmented reality?		
Yes	51	83.6%
No	10	16.4%

Table 4. Answers to question 3

Did the activity help you repeat the lesson of biology?		
Yes	58	95.1%
No	3	4.9%

Table 5. Answers to question 4

Did the apps help you understand the anatomy?		
Yes	58	95.1%
No	3	4.9%

The last task for the students was to identify endocrine glands in individual anatomical systems in the application "Anatomy 4D". The application offered English anatomical names. Some students accepted it as a challenge and began to search the terms on the internet (Table 1, category no. 2, subcategory no. 2). Based on the video-recordings and observations, it was quite clear that the students collaborated to solve their tasks; they explained some terms and relations to each other and they performed activities without any major interventions from the teacher (Table 1, category no. 2, subcategory no. 1 and no. 3). For some students, this application caused some reluctance to look at the systems. They expressed it with statements like "That's weird", "That's disgusting" or "That's awful" (Table 1, category no. 3, subcategory no. 3). 6.6 % of students did not like this mobile technology (Table 6). This is also reflected in subcategory no. 3 (Table 1, category no. 1 and no. 3). However, the work with the augmented reality was interesting for 93.4 % of the students and 98.4 % of students admitted that biology lessons would be more fun if augmented reality was used (Table 6 and 7).

Table 6. Answers to question 5

Did you like the augmented reality activities during the biology lesson?		
It was interesting	57	93.4%
It was not interesting	4	6.6%

Table 7. Answers to question 6

Do you think a biology lesson would be more fun with the use of augmented reality?		
Yes	60	98.4%
No	1	1.6%

Our results confirm the use of mobile technologies during study is a very actual topic. Up to 83.6 % of students use a smartphone or tablet to learn (Table 8). Students use a smartphone or tablet to search for information (91.8 %), to read online study materials (59 %), and to view e-learning study materials (41 %) (Table 9). 62.3 % of students think the mobile technologies are useful in teaching biology (Table 10), and 85.3 % of students think it is effective if students are more likely to use smartphones and tablets to teach biology (Table 11).

Table 8. Answers to question 7

Do you use a smartphone/tablet to learn?		
Yes	51	83.6%
No	10	16.4%

Table 9. Answers to question 8

How do you use a smartphone/tablet while you study?		
I'm looking for information	56	91.8%
I read online study materials	36	59.0%
I look at e-learning study materials	25	41.0%
I do not use it to learn	5	8.2%

Table 10. Answers to question 9

Do you think the mobile technologies are useful in teaching biology?		
It is very useful	38	62.3%
It is only a little interesting	20	32.8%
I cannot judge	3	4.9%

Table 11. Answers to question 10

Would it be more effective if students used smartphones/tablets in biology?		
Definitely yes	24	39.4%
Probably yes	28	45.9%
Probably no	6	9.8%
I do not know	3	4.9%

In terms of the categories we established, the category of the manipulation activities was the most extensive (Table 1, category no. 3, subcategory no. 1 and no. 2). The students immensely enjoyed the manipulation activities. They improved their manipulation ability by mobile technology of visualisation and in their communication, collaboration prevailed. It was again something new to them.

4. Discussion

The simplicity and mobility of mobile devices allows for more effective learning and retainment of knowledge (Balog, Pribeanu, 2010; Kaufmann et al., 2000). Education can be viewed as the externally facilitated development of knowledge. This external influence can take many forms (a teacher, textbook, computer program). The role of visualisation in the educational context is to facilitate the learning of knowledge (Segenchuk, 1997). Using AR features, like one of the visualisation methods, students should facilitate the learning of complex subjects and should not have the problem of remembering information for a longer period of time (Azuma et al., 2011). Our findings confirm that most of the students recognised that mobile technology helped them to repeat the lesson and helped them understand human anatomy. However, it is important to connect visualisation with the knowledge that the student already controls (Segenchuk, 1997). Therefore, we used the AR method in the lesson, repeating the curriculum in the form of neurohumoral regulation of growth and development. It appears that the use of AR technology in the education of complex subjects is effective. Students are moving from instructed learning to a self-centred learning method. Although technological intervention has been present in education for a long time, AR technology has not been fully accepted (Azuma et al., 2011). Many previous studies even state that AR technology has been ignored in education, particularly in university education (Chu et al., 2010; Tsai et al., 2012). According to Billinghurst (2002), this technology is still underutilised, because there is still a shortage of qualified teachers who are able to teach complex subjects using augmented reality (Dunser et al., 2012). Another issue in introducing AR technologies into the teaching process is the lack of material and technical provision of the university. During our research, we experienced Wi-Fi internet connection problems, which sometimes made it difficult to load the AR applications, reducing the effectiveness of using tablets and AR applications in biology. In general, researchers in educational technology are in agreement that more motivation studies of AR as a learning method are needed (Chen et al., 2017; Lee et al., 2012; Margetis et al., 2012; Rogers, 2012). The use of AR technology in education could help students improve their knowledge of the subject, increase their motivation to learn, and ultimately improve their own involvement in the learning process. The AR application of anatomy (like “The Brain iExplore” and “Anatomy 4D”) will assist them in learning human anatomy using enhanced materials that stimulate their interest. Based on the study results, we encourage higher education institutions to accept AR application because visual demonstration and visualisation in the educational process brings a faster understanding of the subject in the curriculum and increases the interest in learning complex subjects.

5. Conclusion

Previous study was focused on analysing the use of mobile technology, manipulation activities, and visualisation in the science and engineering education of biology, based on constructivist and constructionist concepts. Using a combined method of evaluating results (qualitative pedagogical research relied on a description of teacher observation and video and quantitative research consisted of questionnaires on student interest in this type of teaching), we evaluated the efficacy of tablet use in the learning process and the benefits of visualisation in teaching. We believe that by using this method, students’ understanding was deeper, their motivation was greater, and, last but not least, their creativity was strongly supported. In conclusion, students were motivated by the new method, they cooperated very well, and learning was constructive. They gained new knowledge and collaborated. Students applied corresponding cognitive tools, such as thinking and speech, in connection with the cognitive prostheses available in their surroundings. Their minds were thus formed in a different way, which means that digital technology and visualisation delimit and structure cognitive schemes in a way that would be unfamiliar to students of previous decades.

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