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ORIGINAL RESEARCH ARTICLE

Integration of mobile augmented reality (MAR) applications into biology laboratory: Anatomic structure of the heart

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The purpose of the current study is to design and develop a sample Mobile Augmented Reality (MAR) application addressing the anatomic structure of the heart in a way suitable for laboratory learning for pre-service science teachers to achieve learning by constructing information in biology instruction. The implementation of the MAR design activity was conducted with the participation of 30 pre-service teachers taking the biology laboratory course. The implementation process of the activity consists of four stages. The first stage includes the introduction of the MAR application program and marker; the second stage includes the use of the MAR application in a laboratory environment; the third stage includes the operation of dissection and the last stage includes the association of the MAR application with the operation of dissection and general evaluation. Then, semi-structured interviews were conducted by involving pre-service teachers and the data obtained from these interviews revealed that integration of heart dissection with MAR application helped the pre-service teachers to better understand the anatomic structure of the heart and the related concepts. Thus, a sample activity demonstrating how MAR, which is an instructional method with strong potential for reification and visualisation, can be integrated into the teaching of concepts in laboratory settings was developed.

Keywords: Biology education; biology instruction; technology application; mobil augmented reality; heart dissection

To access the supplementary material, please visit the article landing page

Introduction

Biology is a discipline that examines and explains the structure, function, development and classification of life and living organisms. This discipline deals with all biological events that affect living organisms on the planet, from macroscopic to microscopic (Doğan and Ay 2013). The fact that the concepts constituting the scientific knowledge in this discipline are abstract and foreign to students, and that the relationships between the concepts are complicated make teaching biology difficult (Akpınar 2006; Kılıç and Sağlam 2004). Failure to embody these concepts in learning environments leads to the emergence of a sense of failure on the part of

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students making them dislike the biology course over time (Elgün and Kaya 2015; Kırılmazkaya and Kırbağ-Zengin 2016; Köse, Ayas, and Uşak 2006; Lukin 2013). For example, as the division of cells or the infiltration of renal nephrons involves a complex and abstract set of biological phenomena, and it is not very likely for students to encounter or directly interact with such biological events in their daily lives, different understandings can be developed by students in the learning of related topics (Lawson 1988; Yip 1998).

One of the topics in biology that students cannot directly observe and not spatially construct in their minds, and therefore have misconceptions about, is that of the heart which is an element of the circulatory system (Bahar *et al.* 2008; Lawson 1988; Yeşilyurt and Gül 2012; Yip 1998). Yeşilyurt and Gül (2012) found that students had misconceptions about the contraction of the heart (40% of the students), anatomical structure of the heart (56% of the students) and the circulation of the blood in the heart (51% of the students). In addition, Bahar *et al.* (2008) found that 70% of students have misconceptions regarding the anatomical structure of the heart based on the drawings of pre-service science teachers. In particular, the right and left parts of the heart resulting from its physiological structure, determination of the veins entering and exiting the heart, some biological developments occurring in the systolic–diastolic phases of the heart are topics that confuse students and are not clearly understood. In this context, the use of new-generation teaching tools has come to the forefront in order to both construct the structures visually in the mind and eliminate misconceptions because it is seen that the existing educational environments are inadequate in meeting the differentiated expectations of today's students who are popularly referred to as generation z (Chen, Scott, and Stevens 2018; Somyürek 2014). Therefore, it is necessary to reshape the teaching environments in order to enable the use of innovative technologies (Somyürek 2014). In this respect, enrichment of teaching can be achieved by using the strengths of innovative technologies in cases where the objects are not visible (e.g. cell model, DNA structure) or where the conditions do not allow them to be seen (e.g. heart, eye, stomach, lung, kidney, etc.). Thus, students' interest can be directed to the related field and skill of using technology in the teaching environment can be improved. Today, it is seen that many educational technologies with different features are used. Examples of these applications include animation, simulation, robotic coding, mobile learning, wearable technology, hologram, digital storytelling and digital games (Günüç 2017; Johnson *et al*. 2015). In addition to these technologies, augmented reality applications that offer both 2D and 3D audio and video environments through mobile devices are among the emerging technologies (Somyürek 2014).

Mobile Augmented Reality (MAR) is defined as a platform where simultaneous interaction between virtual and real objects is achieved by adding virtual objects onto real images (Azuma 1997; Zachary *et al*. 1997). Through its features, MAR technology provides 3D learning environments that allow students to do more than what they would be able to do in the classroom environment and helps them to develop some special skills by providing a more interactive environment (Özdemir 2017). Moreover, MAG technology has some unique properties such as generating integration between real and visual environments, reifying abstract concepts and catering to more than one sense through multimedia (Billinghurst and Kato 2002). MAR applications enable the visualisation of concepts, make them concrete and provide an interesting learning environment by activating students' spatial skills during the learning of the related concept. Particularly during teaching biology, it

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is important for students to understand 3-dimensional concepts in learning environments and to visually construct them in their minds. In this way, both students' negative perceptions towards biology learning will be reduced and related concepts will be construed more easily. Furthermore, delivery of biology teaching using such technological applications will increase the academic achievement of students (Klopfer and Squire 2008; Sumadio and Rambli 2010). In this context, the multi-media and visual content provided by MAR technology will enable students to participate in the learning process by using their sense organs to a greater extent and enable them to undergo more permanent learning (Gürdal, Şahin, and Yalçınkaya 2002).

In this regard, the purpose of the current research is to realise the integration of MAR applications into the teaching of the structure of the heart, which is a topic of biology addressed within the circulatory system and to present a sample activity about how this integration can be accomplished.

Objectives

When the anatomical structure of the heart within the circulation system is explained in the laboratory classes using MAR applications, it is expected that the pre-service teachers should achieve some cognitive, affective and skill-related goals regarding the augmented reality technology. These learning goals are as follows;

Oriented to cognitive level;

- ✓ Determining the right and left sides of the heart according to the anatomic posture,
- ✓ Determining the atria and ventricles of the heart,
- ✓ Observing the contraction and relaxation movements of the heart,
- ✓ Observing the valves between the atria and ventricles of the heart,
- ✓ Determining the veins entering and exiting the heart,
- ✓ Defining the micro and systematic blood circulation,
- ✓ Relating the concept of pulse to daily life,
- ✓ Evaluating the concepts of systole and diastole in terms of health,
- ✓ Discussing the factors affecting the heart health.

Oriented to affective level;

- ✓ Developing positive attitudes towards biology laboratory,
- ✓ Developing positive attitudes towards technology,
- ✓ Increasing the level of motivation towards the biology course.

Oriented to skills;

- ✓ Developing scientific process skills (observation, inference, prediction etc.).

Oriented to augmented reality technology;

- ✓ Introducing MAR applications,
- ✓ Achieving the integration of MAR applications into daily life.

Participants and implementation of the MAR design activities

The researchers engaged second-year students from the Department of Science Education in the Education Faculty of a state university in the spring 2018–2019 academic year as participants. The activity involved the participation of 30 pre-service teachers taking the course 'General Biology Laboratory II' in the biology laboratory. The instructional process consists of four stages. The first stage includes the introduction of MAR application program and marker to the pre-service teachers which gets them ready for the adequate usage of the application. The second stage includes the individual implementation and evaluation of MAR application in a laboratory environment by means of indicators used by the pre-service teachers in line with the questions of the researchers. The third stage includes performing the dissection of the heart in a group operation in the laboratory environment. The last stage includes the association of the MAR application with the dissection operation and discussion of the findings and the procedures involved during the entire process. In line with these stages, the teaching of the structure and functions of the heart in the circulatory system has been carried out by using MAR application.

Tools and equipment used

- ✓ Mobile phone
- ✓ Calf or sheep heart
- ✓ Dissection cuvette
- ✓ Lancet
- ✓ Scissors
- ✓ Glass rod
- ✓ Gloves

Procedure

First stage (introduction)

In this stage, the MAR application and its marker used in the instructional process of the current study were introduced to the pre-service teachers and they were instructed regarding its use. First, the pre-service teachers were asked to follow the instructions on the marker paper and download the 'Heart AR' application from Google Play Store to their mobile phones. Secondly, the pre-service teachers made the application they had downloaded ready based on the instructions on the marker paper and conducted some investigations (Application 1. Marker Paper). In the Heart AR application, there is a three-dimensional heart model depicting the structure of the heart, the chambers of the heart, the veins entering and exiting the respective chambers and the contraction and relaxation movements of the heart (Figure 1).

Second stage (MAR application)

In this stage, the MAR application was conducted and examined individually by the pre-service teachers through markers in line with the questions of the researchers. In this connection, a three-dimensional colourful MAR application was used for the pre-service teachers to gain knowledge and experience about the anatomy and working principles of the heart, to better understand the dissection experiment to

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be performed in the laboratory setting and to distinguish the structures better. Each pre-service teacher activated the MAR application using their own mobile phone and marker paper (Figure 2). While the pre-service teachers visually examined the anatomical structure of the heart using the MAR application on one hand, they answered various questions about this structure on the worksheet that required questioning on the other (Application 2. Worksheet: Structure of the Heart). For example, the pre-service teachers were asked the question 'What is the right and left part of the heart in MAR application according to the anatomical position of the heart in our body?' and discussions were conducted under the guidance of an instructor to integrate the application into the teaching process interactively.

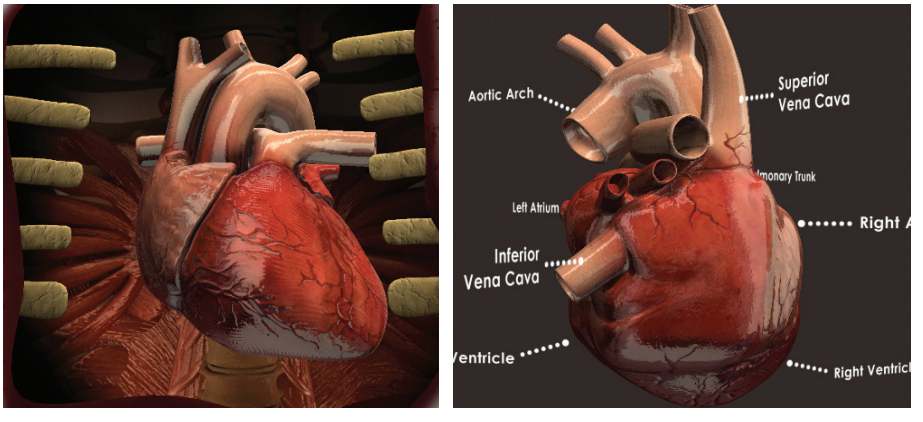

Figure 1. Heart AR MAR Application.

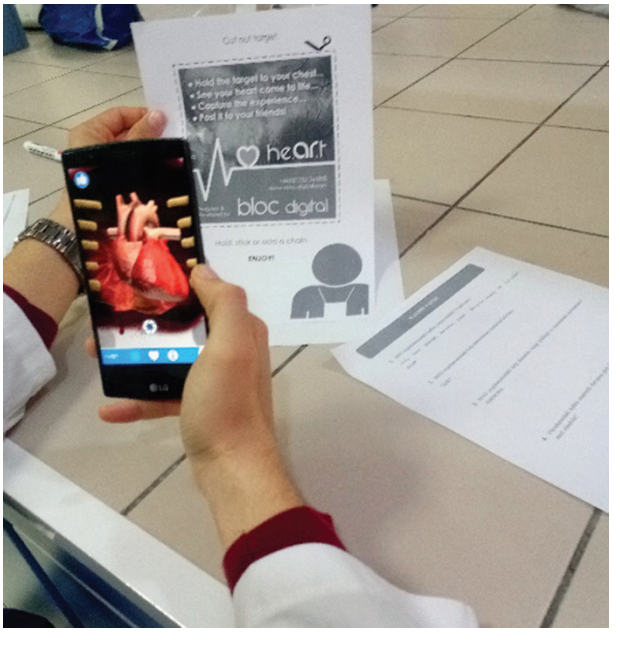

Figure 2. Individual Investigation of the MAR Application .

With the aid of the MAR application, the pre-service teachers found an opportunity to visually see and construct in their minds the parts that make up the heart's three-dimensional anatomical structure, such as the atrium and ventricle veins as they enter and exit the heart, the path followed by blood through the heart and the direction of blood circulation inside the heart (Figure 3).

Third stage (dissection)

In this stage, dissection of the organ to be examined in the laboratory setting was performed by the pre-service teachers in groups. First, the instructor performed a sample dissection procedure using the demonstration method to show how to determine the right and left lobes and veins of the heart in the anatomical structure of a calf's heart in such a way as to be seen by each group (Figure 4). Moreover, the pre-service teachers

Figure 3. Pre-Service Teachers' Interaction with the MAR Application.

Figure 4. Heart Dissection Performed by the Instructor.

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were also informed about what should be taken into consideration while performing the dissection operation (Figure 5 and Application 3. Instruction Manual for the Experiment). It was also emphasised by the instructor that the pre-service teachers should be careful in the use of cutting and piercing tools such as the scalpel.

The pre-service teachers examined the anatomical structure of the heart specimen by performing the heart dissection procedure according to the instructions given (Application 3. Instruction Manual for the Experiment). In addition, after the dissection procedure, the pre-service teachers conducted group discussions about the anatomical structure of the heart, the determination of the right, left parts and chambers, the detection of atria and ventricles, which atria and ventricular veins are connected and the direction of blood flow.

Fourth stage (relating and evaluating)

In this stage, associations were made as a result of the investigation of the anatomical structure of the heart using both MAR application and dissection, and they were related to daily life. The associations and discussions were made according to the questions in the worksheet (Application 4. Worksheet: MAR and Dissection Relation-Heart). In this context, the pre-service teachers made evaluations by explaining which of the structures in the MAR application were concretely observed during the dissection operation, how the determination of the structures was performed and what the relationships between these structures were.

Figure 5. Heart Dissection Performed by the Pre-Service Teachers in a Group.

Findings, conclusion and discussion

As a result of the current study, a sample MAR application activity addressing the anatomic structure of the heart in a way suitable for laboratory learning for pre-service science teachers to achieve learning by constructing information imparted during biology classes was designed and developed. With this activity, MAR application and marker were introduced to the pre-service teachers and anatomical structure of the heart was examined visually using this application. The answers given by the pre-service teachers for the cognitive questions about the structure of the heart in the worksheets (Applications 2 and 4) were evaluated by the practitioners. This evaluation was made out of 100. As a result of this evaluation process, 80% of 35 pre-service teachers were found to have scores of 70 points or higher. Thus, it can be argued that the pre-service teachers achieved some developments in line with the goals set at the cognitive level. Moreover, it was found that the pre-service teachers established an interactive interaction with the three-dimensional visual of the structure of the heart. Similarly, in the literature, it is stated that MAR applications facilitate students' learning and increase their success in biology teaching (Erbaş 2016; Küçük 2015; Perez-Lopez and Contero 2013). In particular, Perez-Lopez and Contero (2013) stated that the use of 3D model and animation-supported MAR application while studying the subject of the circulatory system facilitated students' learning and understanding due to the increase in their interest and motivation generated. In addition, examination of the anatomical structure of the heart using the MAR application provided the pre-service teachers with the opportunity to be informed about the anatomy and parts of the heart before they got engaged in the dissection operation; moreover, this application also gave information about the functions of the parts of the heart; thus, the pre-service teachers were able to make comparisons while performing the dissection and MAR application were very useful in learn about subjects of biology such as the heart because MAR applications provide students with a rich content related to the subject or concept of interest; they also make small structures that are difficult to observe visible and create opportunities for students to learn by living (Abdusselam 2014; Dunleavy and Dede 2014; Wu *et al*. 2013).

The pre-service teachers had the opportunity to observe the anatomical structure of the heart in a realistic and concrete way through dissection operation they performed during the activity process. In this context, the pre-service teachers compared the MAR application with the dissection process and attained a holistic learning experience. In this way, various sense organs of the pre-service teachers were activated and laboratory activities were rendered to be more enjoyable by facilitating their learning. Similarly, Yılmaz and Batdı (2016) stated that augmented reality applications play an active role in making the course more enjoyable. In this context, dissection operations performed in a pleasant laboratory environment via the augmented reality applications can contribute to the development of pre-service teachers' skills such as observation, inference and prediction in the laboratory environment. Research shows that MAR technology positively affects students' laboratory skills (Cai, Wang, and Chiang 2014; Chen and Tsai 2012). In addition, MAR technology improves students' spatial abilities and fosters their visual reasoning skills (Radu 2014; Salmi, Sotiriou, and Bogne 2010).

After the completion of the MAG applications, semi-structured interviews were conducted by involving the pre-service teachers. In these interviews, the pre-service teachers were asked questions such as 'Do you want other biology topics to be taught

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through the support of MAG applications? Why?' and 'Do you want to use MAG applications in your own classes when you become a teacher? Why?'. As a result of the analysis of these answers by the practitioners, it was concluded that the pre-service teachers think the MAG applications should be used in biology teaching and that they are useful in creating interesting and enjoyable learning environments. Thus, it can be argued that MAG applications played an important role in increasing pre-service teachers' motivation and attitudes towards the course. In the relevant literature, it is seen that MAR applications increase students' attitudes and motivation towards the course (Hsiao, Chen, and Huang 2012; Wojciechowski and Cellary 2013; Yıldırım 2016). This might be because through augmented reality applications, abstract concepts can be made more clear students. In their study, Wu *et al.* (2013) stated that augmented reality applications increase students' perception of reality and develop their affective characteristics by facilitating learning. In summary, the use of MAR is recommended for learning the anatomical structure of the heart, which is addressed within the scope of the circulatory system that is part of a biology course and includes abstract concepts. In addition, it is important that the MAR application should be handled in stages as mentioned in this study and that students are actively involved in the learning process.

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