Exploring AR and Tangible Objects in the context of Teaching Anatomy in Middle School

ABDULRAHMAN, AEMA, AL-ERYANI
Faculty of Arts and Communication, Malmö University, abdulrahman.e.m.aleryani@gmail.com

LUCAS, LAK, KASA
Faculty of Arts and Communication, Malmö University, lucas.kasa@hotmail.se

IVAR, IL, LUNDIN
Faculty of Arts and Communication, Malmö University, ivarlundin@gmail.com

CHLOÉ, CMI, ISMAILY
Faculty of Arts and Communication, Malmö University, chloeismaily@gmail.com

Dissection is deemed as an unideal experience for middle school students. In this paper, the focus is to explore how Augmented Reality (AR) could be implemented into the dissection aspect of learning anatomy. An evaluation of how AR performs in education is explored as well as an analysis of the importance of dissection in anatomy learning in Middle School. A look & feel prototype was developed to explore the physical qualities of a heart model. For the implementation prototype we merged the heart model with an augmented reality overlay to experience the components together. Furthermore, the notion of "grossness" is discussed, to understand another aspect that might be considered problematic regarding dissection for middle schoolers. From our user testing and literature review, it is strongly likely that a moderate amount of disgust plays a positive role in dissection and helps recollect information. Finally, it is deduced that further research needs to be done in the topic of collaboration between students when using AR as a tool in the classroom as it also plays an important role in this experience.

CCS CONCEPTS • Applied computing • Education • Interactive learning environments • Human-centred computing • Interaction design

Additional Keywords and Phrases: AR, Augmented Reality, Education, Medicine; Anatomy, Tangible Learning, Dissection

1 INTRODUCTION

Augmented Reality (AR) is increasing in relevance and use in our everyday life. AR was first introduced in the 1950s by Morton Heilig as the pioneer of the concept, where he envisioned the implementation of all the senses [1]. In 1962 Heilig introduced Sensorama, the aim was to make the experience of the theater become more captivating. Although the digital means back then were not as developed as they are today, it still provided us with an understanding of the potential of the technology. In today's world, AR can take many forms which could benefit our everyday life. The different types of AR that are being used include head-mounted displays such as Google glasses, computers, handheld devices such as phones and tablets. The use of AR is becoming more prevalent in different contexts. The context that we found interesting is education, we will evaluate the advantages and disadvantages of AR. Furthermore, we will look at AR in relation to its use in the medical field. We will evaluate the advantages and disadvantages of implementing AR into learning anatomy in relation to dissection.

We will also present a case study looking at both the look & feel dimensions of the prototype as well as the implementation dimension. Our primary user group will be students in the age group between 10 and 13 years old. The aim of this case study is to implement AR into the dissection aspect since dissection at times could be deemed as an unideal experience for students. Utilizing AR could present the idea of dissection gradually and minimize bad experiences for students. An example would be that the reaction to smell and blood would be non-existent when using AR, however the students would still acquire the same knowledge.

2 BACKGROUND

This section will present the different interpretations of AR and its evolution over time. The advantages and disadvantages of using AR in Education as well as the importance of dissection in anatomy will also be discussed. AR can be a tool to welcome multiple learning styles in education.

2.1 Definitions of AR

Hsin-Kai Wu et al. [2] argue that AR has been defined diversely within the field. Milgram et al. [3] categorize AR into two approaches: the broad approach and the restricted approach. The broad approach is explained as "augmenting natural feedback to the operator with simulated cues" [2:42, 3] while the restricted approach is "a form of virtual reality where the participant's head-mounted display is transparent, allowing a clear view of the real world" [2:42, 3]. Azuma [4, 5] defines AR using three different criteria, two of them that we find relevant. The first criterion is that the AR has to be able to combine real and virtual spaces in order to produce a mixed reality. The second criterion is that AR is intuitive through-out time. The third criterion is that it has to recognize a 3D object as the input to be scanned and a 3D virtual object outputted through the AR. Although, this last criterion is not relevant for our project. Klopfer [2, 6] proposes a mixture of augmented and tangible objects that convey relevant data to the user through AR.

2.2 AR In Education

AR can be used in education, but it entails both positive and negative effects. Radu [7] offers an overview of issues and opportunities for the implementation of AR in education. The learning outcomes while using AR has been proven to be a superior option compared to textbooks as well as purely digital mediums. Studies have shown that AR could improve the outcome of physical tasks by allowing the user to perform with greater precision. Henderson & Feiner [7, 8, 9] express that using AR improved the way military mechanics restored and the way they conducted upkeep on their vehicles. Chen et al. [7, 10] argued that children who learned using AR provided a higher score than children who learned by using a textbook. There are benefits to short term and long-term memory when acquiring knowledge through AR. Macchiarella et al. [7, 11, 12] also provide insights that indicate that the long-term memory of the taught subject did not decay as quickly while using AR.

A study conducted by Freitas & Campos [7, 13] indicates that collaboration between the students increased while using AR on a shared screen. Kaufmann & Dunser's [7, 14] report specified that students who learned 3-dimensional structures expressed that using AR felt more rewarding than using a PC program to learn. AR brings the opportunity for students to learn through embodied interactions [7]. In an educational setting that would mean that students do not need to fundamentally sit down and passively learn through listening to lectures or screens.

On the contrary, AR needs the user's attention, meaning that it is easy for some students to lose valuable instructions to carry out the given assignment. Furthermore, a student is more likely to recognize an error when using AR compared to non-AR, as AR is a more explorative method [15]. Morrison et al. [16] express how students "pay more attention when using the AR system with a paper map than compared to a purely digital GPS-based map." [7:1536-1537]. This could be used as an opportunity to implement both a physical object that draws on the body while recognizing relevant information by using the AR. In the case study conducted by Morrison et al. [16], the students felt that using the AR system of the map was difficult in comparison to the non-AR alternative [7, 16]. By using AR in the classroom there is lower participation. It is argued in a study by Kerawalla et al. [17] that while teachers were in the room the engagement level was lower for students using AR than that of non-AR methods [7]. In a study by Freitas & Campos [7, 13], they saw that the implementation of AR was not always a successful way of learning. They found that AR is not suitable for the high achieving students to acquire similar improvements in their knowledge to that of their peers. Hornecker and Dunser [18] put forward information that the students who do not have high skills in reading found themselves in a similar predicament when texts are used within AR.

2.3 Importance of Dissection in Anatomy Learning

Dissection has been historically used without innovation to the methods of learning anatomy, as the benefits are debated nowadays. Kurt et al. [19] argue that dissection is of importance in anatomy where the students learn through three-dimensional structures which builds their knowledge of anatomy through dissecting cadavers. Kamphuis et al. [5] argue that dissection could allow for more elaborative experiences when it comes to the knowledge that has been previously taught by textbooks or lectures. On the other hand, Kamphuis et al. [5] also argue that even though dissecting is a valuable way of learning anatomy, dissecting is costly and that it has yet not been proven to allow the learning to be more effective. Moreover, using cadavers for learning anatomy is that the bodies that are preserved for dissection contain formaldehyde [20]. Which is a strong chemical that is used to prevent decay and can have health consequences if one is exposed too long to it. This could affect the student's respiratory system as well as their eyes or cause several other health issues. Another issue for the students could be the strong odour from the formaldehyde, which could provide the students with a negative connotation within the dissection process.

2.4 The Different Types of Learners

Students learn differently, this means that there are other ways for them to gain valuable knowledge which they may retain easier. Visualization is one of the main aspects where there is potential for students to retain knowledge through seeing three-dimensional structures that can be manipulated [5]. Touch is a valuable means for educational use, which offers the possibility of getting feedback based on the user's actions towards the object [5]. Blum et al. [5, 21] conducted a project where AR was used in connection to Kinect. It was created in relation to teaching anatomy for university level learning. The users would be able to see themselves on the screen where the augmented part would be that they can see the inside of their body in relation to the CT dataset [5, 21]. Using Kinect means that it is a cost-effective material for education in comparison to real dissection [5]. Furthermore, Kamphuis et al. [5] provide another insight into how learning could become more meaningful for the students. They highlight five concepts; these concepts are described by Kamphuis et al. [5] as follows: Active learning means that the user will learn by performing a task. Constructive learning uses new encounters with already obtained skills. Intentional is when the actions are aim-oriented. Authentic learning is when the skill gained is modified in difficulty in the AR environment. Cooperative learning is when the students have to work together as well as communicating in order to solve the task. AR can build on the learning of relevant knowledge that can be applied to other scenarios. By using 3D augmented visualization, the student can have an experience that is like that of the real task. This could increase the learning experience without disturbances, and it could also provide the user with knowledge and visuals of aspects that would not be comprehended without the use of AR. An advantage for using AR is that the user would be given continuous feedback which gives the student the opportunity to oversee their own learning [5]. "AR learning environments can provide situated just-in-time and just-in-place learning."[5:302]. This means that there is a possibility for a more diverse option within the experience.

3 METHODOLOGY

Based on the studies mentioned previously, AR seems to be a tool with the potential to complement dissections. In Europe, students usually do dissections in middle school however its utility is still debated nowadays. Furthermore, students with fear of blood or who get disgusted with the sight of it are excluded from the experience. With that in mind, is it necessary for middle schoolers to dissect living beings or is it safe to resort to a less accurate but more inclusive activity? Due to its historical use, perhaps the emotional impact dissections have on students is what makes it memorable and therefore still used nowadays to teach basic anatomy? What we propose in this paper is an alternative to dissection, one that is complemented with AR.

When prototyping for this project, the framework proposed in The Anatomy of Prototypes: Prototypes as Manifestations of Design Ideas by Young-Kyung Lim, Erik Stolterman, and Josh Tenenberg [22] was used. This paper was used with the intention of making the prototyping process as effective as possible to quickly filter the undesired qualities of a prototype. This means that we would have a higher chance to get reliable feedback from participants during user-testing, but we would plan and utilize material resources more effectively.

To test our ideas, we have decided to create two kinds of prototypes. The first one is a look & feel prototype to test the appearance of the tangible object and how much information one can retain when manipulating it. The second one is an implementation prototype that tests the functionality and spatial structure of the AR application combined with the tangible object. Figure 1 illustrates how the whole system would function. Models with texture mimicking the real anatomical parts and tracking-markers enabling physical interaction and arranging of components. Lastly, the models have tracking markers on top for the AR-application that renders realistic textures on top of the models and contributes with educational annotations on top of them.

Figure 1: Whole system incorporating AR mobile-application and physical models.

3.1 Look & Feel Prototype

The Look & Feel prototype is supposed to test the tangible part of the user interaction with the system. The following hypotheses are tested here: the "grossness" and disgust experienced when dissecting a real heart is what makes an experience memorable, there is a way to mimic a real dissection without sacrificing an anatomical accuracy. The overall *appearance* of the heart will be considered, that includes texture, material, and other liquids, and filter those qualities of the prototype.

3.1.1 Creating the Heart

The first component of this look and feel prototype consists of a heart. We are using a Halloween decoration for this experiment (see Figure 2). The heart is as anatomically accurate as we could find. Although there is an advantage in customizing the heart and choosing the material ourselves, we decided to go with a common Halloween decoration for us to be able to rapidly test.

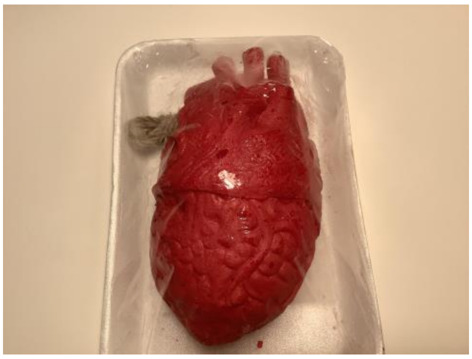

Figure 2: Fake heart

However, after testing with various liquids like oils and dish soap, we discovered that the heart's surface was porous therefore any substance we poured on it would get absorbed after a few minutes. This led us to use this plastic Halloween decoration as a cast for a new heart.

The material we used to create a new heart is candle gel. This would make the heat more jelly, like a real heart would be. Furthermore, this new material would not dissolve or absorb any liquid that we would pour onto it. Another advantage of this material is that it could be re-melted and reused multiple times. While using the heart for user-testing dish soap was poured onto it to mimic blood.

3.2 Implementation Prototype

The implementation prototype tests how the AR app performs alongside the model. Ideally, the application would recognize a dissected or cut heart to show the user how the ventricles and atriums contract, the valves open and close, and the blood flow. In order to reproduce that experience, we decided to use Blippar, a free AR application that offers users the possibility to create their own AR experience and test it in the application. For the application to recognize the open heart and display the information and animation on it, a marker was placed inside of it so that, when cut in half, this marker would reveal itself (see Figure 3). The use of markers can be beneficial in relation to the third criteria by Azuma, as previously mentioned. We see it as an opportunity to have the AR content change once the user reaches an area where new information can be presented through AR which leads to more dynamic use.

Figure 3: AR application displaying information over the heart model

3.3 User-testing the Implementation and Look & Feel Prototype

This experiment was conducted with two participants: one female (will be referred to as Participant 1) and one male (will be referred to as Participant 2) who were tested individually. The following protocol was followed during user testing to standardize the testing:

1. Participants are asked to sit by the testing table and to put on the latex gloves available at the table.
2. Participants are asked to touch or grab the heart in front of them and give their first impressions. From here three questions are asked:
   - If you couldn't see what you were touching, do you think this could pass as a heart if you were told it was that in the first place? (Here we are aiming to understand if the texture of the prototype is correct)
   - Does this "gross you out" or disgust you?
   - Can you tell me from a scale of 1 to 10 how "gross" or disgusting do you think this is? 1 being not at all and 10 being very gross (or cannot touch the model).
3. While still manipulating the heart, participants were explained and asked to memorize a couple of parts of the heart, more specifically the following four:
   - The superior and inferior vena cava: Where the used blood comes into the heart.
   - The pulmonary artery: Where the used blood passes to be sent to the lungs.
   - The pulmonary veins: Where the healthy blood comes in from lungs.
   - The aorta: Where the healthy blood passes to be distributed throughout the body.

   This information was repeated twice and pointed out in the heart model where they are.
4. Here the participants learned about the intent of this study and how it is aimed to develop in the future, giving them an opportunity to give more input on the project in general.
5. Participants were shown an AR animation over the heart model, showing the blood flow and how the different parts of the heart they had to memorize functioned (as seen in Figure 3). Their reactions and comments were carefully recorded. If more clarification was needed, some questions were followed.
6. Participants were asked to recall as many of the heart parts as possible. Due to the length of the definition and the short amount of time they had to memorize, a definition was given at first. This meant that they had to recall what part of the heart corresponded to the definition. A score out of four was created depending on their performance. Approximate answers or mispronunciations did not count as a correct answer.

3.4 Phone Holder

Figure 4: Cardboard phone holder prototype building instructions and the real low-fidelity prototype.

For the user to perform the dissection, it was essential for them to have their hands free. To solve that problem, we have designed a low fidelity prototype of a phone holder (see Figure 4) that could be worn by the user so that they could observe what was going on in the AR application and do the dissection simultaneously. As mentioned previously, one of Kamphuis' five concepts for meaningful learning includes Active Learning, meaning that we needed to remove anything that would hinder students from performing the dissection with AR.

4 DISCUSSION

4.1 Findings from Prototyping and User-testing

Participant 1 (female) scored 3/4 and rated the grossness at 1/10. She described the model as cold and jelly-like. When asked what she would think she was touching if she could not look at it, she commented: "I wouldn't say that this is a heart, but I would say that it feels like an organ without looking at it...and if it was not as cold." When given the definition and explaining the function of certain anatomical parts of the heart, the participant did mention that she goes frequently to the cardiologist so they are familiar with the terminology used in the experiment and commented that it might be one of the reasons she scored high. Participant 2 (male) scored 2/4 and rated the grossness at 3/10. This participant has a fear of blood and needles which would explain why they were more uncomfortable with the model than Participant 1. Despite scoring worse when recalling the heart parts, he added: "I was a little grossed out but I don't feel like it got in the way of learning".

4.2 User-testing Critique

First, due to the ongoing pandemic of COVID-19, the participant pool was greatly reduced therefore the opinions stated by the participants have yet to be validated with a larger group to draw any conclusions, but the notion of embodiment enhancing learning has been advocated by various teaching methods for instance the Montessori method of teaching where tangible tools often are used in learning. Furthermore, augmented reality in its essence is about changing the environment around the user which could be an immersive experience, can we use this opportunity for greater purposes than recreational ones? Just like videogames, there is an opportunity to use the addictive qualities for educational purposes.

Furthermore, the participants were also family members. The problem with this is that people that are close to the researchers can end-up trying to do their best to please the researcher or confirming their biases. This is something that was taken into consideration when conducting the experiment.

4.3 Relationship between Disgust and Curiosity

Previous research has pointed out that feelings of disgust and revolt can co-exist with curiosity given that these negative emotions are moderately experienced [23]. This is something that seems to motivate why dissections have been historically used to teach anatomy in middle school. However, does this mean we cannot design the same experience without having to use real cadavers? Furthermore, this is something that both participants seemed to agree with especially Participant 2 seemed more interested in learning more about the heart once getting used to the sight and the feel of the heart. He also has reported to be moderately disgusted or “grossed-out” but not enough to stop them from participating in the dissection.

The user-testing we did was an attempt to take the user through that emotional journey by giving the interaction a *dramaturgical structure* [24]. Being this involved in an activity gives users an opportunity to participate in a more embodied interaction with the help of AR which is necessary for deep learning.

4.4 Choosing the Fidelity

When designing either a virtual model for the AR environment or the physical counterpart we need to ask ourselves what fidelity should be accomplished and why. Is a realistic model required for teaching anatomy in middle school or could it be taught just as effectively with a more primitive model with simpler textures. One could argue that having a too realistic model is negative, that it could provoke the same reactions as experienced while dissecting real tissue. Furthermore, individuals with strong reactions to seeing blood could in theory be affected by having too realistic graphical representations.

This begs the question: why is dissection disgusting or disturbing for some people? At first thoughts, the fact that there is dead tissue as the main contributor to this reaction – but at the same time, why do some people react repulsively to food waste in the sink? This is not a logical reaction because that food would otherwise be eaten, this fact leads us to think that the tactile qualities have a lot to do with how we interpret a material as gross or disgusting. And with this in mind, should virtual anatomy models be so realistic that the same repulsing reactions are induced – defeating the argument for using virtual dissection instead of regular, real dissection?

And what are the learning objectives? For instance: educating students about the human heart, what is more important, having a realistic heart, or having a graphic representation of where the interactions between the different parts take place? This way, the students could independently take control of their own learning and the textures of the organ in question could be adapted to the learning outcome. The use of annotation could bring a better understanding to an otherwise complex system and could support traditional classroom-based teaching by tutoring the students when practicing independent work.

5 CONCLUSION AND FUTURE WORK

To conclude, it could be beneficial to use AR with other forms of learning, compared to entirely textbooks or computer-based material. AR also provides the possibility to learn through embodied interactions, which means that users can improve their skills by conducting physical tasks with greater precision. Learning through AR is at times unsuccessful, in relation to it being the perfect medium for all students. Visualization and touch combined with AR offers other means for the students to not only obtain but maintain knowledge. Feedback through the student’s interaction provides the opportunity to take control of their own learning. Kamphuis’s framework for creating more meaningful learning for students includes active, constructive, intentional, authentic, and cooperative. The use of dissection on cadavers is debated as it has not been proven to be beneficial. The advantages are that it can be beneficial for the students to learn from physical three-dimensional objects. Moreover, dissection allows students to correlate findings from lectures and books. Contrary, dissection is quite costly. The formaldehyde that is being used to preserve the cadaver has a strong odor. This could lead to respiratory problems as well as negative connotations within the anatomical dissection process. The user-testing was inconclusive, due to us having a low number of participants. Therefore, we cannot confirm or deny that the grossness has its place in dissection. However, the participants agreed that implementing AR would be useful to complement dissection. In regard to future work, we can see that it can be further investigated in relation to collaboration. As we did not have the possibility to conduct any collaborative user testing. There is a possibility to evaluate a shared screen perspective with multiple screens, which would mean different angles from different screens. Evaluation of utilizing multiple screens could also be further investigated. Due to the pandemic, this became an aspect that we did not have the possibility to explore. Augmented Reality itself has already been extensively researched and is not the focus of this paper. The physical heart and the haptic feedback were instead explored to understand better how they change the learning experience of dissection classes in middle school. In this case, having a tangible object that can offer haptic feedback to compliment the AR experience seems to positively influence this learning experience. Further research needs to be made to further understand if the symbiotic relationship between AR and tangible objects (haptic feedback) can be applied to other areas of Tangible and Embodied Interaction.

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