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AUGMENTED REALITY AS A VISUALIZING FACILITATOR IN NURSING EDUCATION

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Abstract

This paper describes the application of augmented reality in the teaching of highly complex anatomical and physiological subjects in the training of nurses at undergraduate level. The general aim of the project is to investigate the potentials of this application in terms of making the complex content and context of these subjects more approachable to the students through the visualization made possible through the use of this technology. The background, hypotheses, nature, design, and results of this initial work are described as well as the methodological approach and the results.

Keywords: Innovation, technology, visualization, augmented reality, research projects, Inquiry-Based Science Education (IBSE).

1 INTRODUCTION

Augmented Reality (AR) as a technology is not new: it has existed for several years and been used in a variety of ways ranging from information services to medical and military uses [1]. Just as it has been used by authorities, museums and national parks to help visualize e.g. sub-surface data [2] or another time/era [3] In addition, it has been used for various games – indoor as well as outdoor [1,4,5]. Many of the uses described in the early literature required highly specialized technological equipment to work [6], making for a natural limitation in the uses, but with the advent and spread of smartphones and with connectivity no longer being a major issue, new, everyday applications have become available as is also seen in some of the museum and natural park uses [3]. However, much of the literature focuses on the technological issues connected to the uses, and little research seems to have been done on the teaching and learning potential of AR. Even in cases where learning potential is discussed it seems, that AR as an educational technology faces one of the common problems of new technologies in education [7]: It is used in a technology-centered rather than a learner-centered approach. Some of the few instances of a pedagogical focus on the uses of AR are found in Juan et al. [8] and in Munnerley et al. [9].

Sometimes, the term is being used to refer to virtual reality, virtual environments – or virtual worlds – as also illustrated in Milgram and Kishino's [10] illustration (fig. 1):

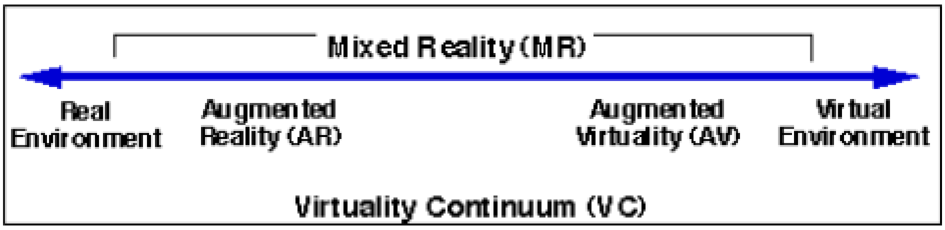

Figure 1: Simplified representation of a "virtuality continuum"[10].

However, in this article, the term AR will be used as defined by Munnerley et al. [9]: "...real-time views of a physical, real-world environment whose elements have been augmented, enhanced, enriched or diminished by computer-generated sensory input, such as sound or graphics as a layer or projection."

1.1 Background

As a technology, AR can visualize processes in the physical world that are otherwise hidden and complex and thus often difficult to fully grasp. Against this background, we initially set out to investigate possible pedagogical affordances, mostly in science subjects across a range of undergraduate programs. We then decided to do a study focused on the teaching of anatomy and physiology in the training of nurses and selected lung anatomy and physiology as an appropriate theme for our first experiment. This was not done to show what the technology could do on its own, but rather because this was a part of the curriculum where the students often experienced great difficulties.

1.1.1 Teaching and learning challenges connected to lung anatomy and physiology

As innumerable factors are involved in the complex and intricate workings of the lungs, this particular area traditionally poses a major challenge to nursing students, and teachers have a limited range of tools to help facilitate student learning. Artefacts traditionally used in the anatomy classroom include skeletons, real-size models of organs, photos, images, films, and drawn models of lungs and respiratory processes, and these usually provide a fragmented view of the body as they focus on only one part, usually not taking a more holistic view of the body. The degree of abstraction required to connect these to the physical human body and its workings in a live person is tremendously high. However, with the degree of *in situ* visualization made possible through AR, the hypothesis is that the application of AR can help increase students' understanding by providing them with a higher degree of transparency of the physical body. Thus, the study aimed to provide new knowledge on the potential transformative power of AR for the teaching and learning of lung anatomy.

1.1.2 Setting

The setting of the study is one of the schools of nursing at VIA University College in Denmark. The anatomy and physiology group is made up of 25 1st-year student nurses. It is a technology-rich environment as the school has a strategic focus on innovation and technology, and there is unlimited, well-functioning, Wi-Fi just as most students have their own smartphones. However, for the experiment, iPads were provided for them.

1.1.3 The app and the experiment

In collaboration with a local GTS Institute[1], an app was developed that shows a set of natural-sized, moving (breathing) lungs. In the production of the actual images of the lungs, realistic and accurate representation was more important than a fancy and appealing "wrapping" and interface. The experiment was carried out as a laboratory experiment and took place in a closed classroom. Students had been informed about the experiment with the app and about filming and recording taking place. They orally agreed to participate. The duration was one lesson – 45 minutes. The subject of the class was the lungs and respiration.

Six students were provided with iPads where the app was installed, and three were given T-shirts with printed logos as markers for the AR app. Students worked in groups of 4-5. For the experiment, three students wore the T-shirts with a tag positioned on the front and back of the shirt so as to activate an app on the iPad providing the illusion of lungs being located and moving inside the person wearing the T-shirt. This allowed other students to investigate with the iPads. As such, it is a simple app as it does not draw on any data connected to the individual wearing the shirt, and thus, it was merely a simple, proof-of-concept app. See fig. 2.

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[1] See http://www.teknologiportalen.dk/EN/About+GTS/About+the+GTS+institutes/ for description of these technology and innovation centers.

Figure 2: T-shirt and iPad

2 METHODOLOGY

2.1 Approach

The general approach to the teaching of science-based subjects that can be seen in this study draws inspiration from the principles behind Inquiry-Based Science Education (IBSE) [11,12]. This approach to learning emphasizes how learners need to be actively involved in the process of learning, just as the focus is on understanding what is learned rather than on rote learning. The approach draws on a social constructivist understanding of learners creating meaning and sense of the world around them through the creation of individual and shared explanatory models [13]. In this way, students construct their understanding through reflection during exploratory processes [13]. In the present study, exploratory ways of working are encouraged and facilitated through the teacher's planning of work forms and tasks in order to support this creation of understanding: for instance, students are engaged in group work where they reflect on the learning content and their learning just as they are actively involved in exploratory and investigative work. Thus the IBSE approach holds that through these working methods, student interest and learning outcome are increased [11]. The app lends itself well to the IBSE-method, since it has no fixed aim or sequence of activities. In other words it is open to the students' own way of inquiry.

As an approach, IBSE is characterized by being participant-controlled, again focused on making the students active explorers engaging in reflection on their learning experiences [11]. In the experiment at hand, the IBSE approach thus allowed students to participate, explore, describe, relate to and use their subject knowledge to reflect on their sensory impressions of the images they were presented with through the app, for instance in terms of what they saw. The students were in no way expected to exert value judgments on the use of images, but merely to activate their subject knowledge and reflect on how what they saw matched or added to this knowledge[2].

In the study at hand, we focus on the students' experience in the use of the app, not on their concrete learning outcome. We merely conducted one experiment, and as such has limited in relation to the general pedagogical affordances of AR. Furthermore, in this article we only present a preliminary analysis of the data although these also lend themselves to further analyses.

When working with the students' use of the app, we employed a "ReflexivityLab" [14] as a tool for capturing, examining and understanding students' experimental processes and interaction with the technology. This tool provides the researcher with a way of working with processual and experimental methods [14].

[2] The questions they were given were: 1. What do you see? Write your won description of what you see. 2. What do you notice when using the app? Explain. 3. Talk to the rest of the group about what you see, and make a shared description and explanation of it.

2.1.1 The ReflexivityLab:

The ReflexivityLab may be described as a room where student action and reflection is encouraged and unfolds and a technology is involved [14]. It is characterized by having participants relating to a technological artefact and is the place where the researcher observes students' reflective work as they choose their own use situation in relation to the app. The ReflexivityLab method is defined [14] as having a "person-in-situation", where the "situation" in our case is the lab. The situation is thus also the place where movement, body language, sounds, speech, and pauses are observed as they occur during the engagement with the new technology and what it allows students to do.

The processes in the lab are filmed using a panoramic camera and two still cameras zooming in on the group activities. This allows the researcher to take an exploratory stance as the data are retained and may be explored over and over in order for the researcher to understand and reflect on them. The center of attention is the person-in-situation and his or her actions in relation to the research question posed.

An aim here is to explore the students' sense-making as reflected in their experience of and reflection on the use of the AR app. In the ReflexivityLab, three types of dialog contribute towards the creation of valuable insight: Processual dialog, working dialog, and reflection dialog. These three are documented and retained in different ways.

Processual dialog: This is the dialog among students during the work with the app. This type of dialog yields information as to student engagement and willingness to use the app. This dialog is accessible through the observations made and the filming of the whole situation, which makes possible the re-viewing of the procedures and the interaction, the uncovering of new perspectives and experiences in the interaction with the technology.

Working dialog: This is the dialog that occurs among students working with the technology. In this study, students were given a written IBSE-based task and questions, which they handed in immediately after finishing the work. Therefore, the working dialog is the dialog that occurred while they were answering the IBSE questions. This dialog is also accessible through the observations and filming.

Reflection dialog: This is the dialog that unfolds during group interviews with students and in their answers to questionnaires. This is accessible and retained through sound recordings of the interviews and through the filled questionnaires. This dialog is elicited immediately after the use of the app, and in it, the students verbalize their response to the use of the app [14]. The aim of the researcher is to gain knowledge of the students' attitudes to the use of the app as well as their view of the potential of the technology.

2.1.2 Evaluative questionnaires:

Finally data was collected through a brief, quantitative questionnaire. This allows for the description of students' immediate evaluation, understanding, and attitude towards the technology used and their assessment of its usefulness. Questionnaires were filled in in paper form. It must be noted that only 14 out of 25 students returned the questionnaires, giving a response rate of 56 %.

3 ANALYSIS AND RESULTS

3.1 Analytical approach

As we have seen, most of the data collected are qualitative, well in line with the approaches employed. All the visual and qualitative data collected is analyzed through meaning condensation [15]. Kvale describes six analytical steps, and they are here used as tools for organizing and analyzing the interview texts and video films and for condensing the meanings into a manageable form. In this study, we only apply four of the steps: 1. Data collection; 2. Informants themselves see new meanings in relation to the central aspects of the study; 3. Through a reading of the interview text[3], the meanings arising from them are condensed: First, the texts are read and viewed in their entirety to provide an understanding of the material as a whole, then the meanings arising from the text are condensed and presented as central themes.; 4. The transcribed data materials are interpreted and analyzed [11].

[3] Both interviews and videos are here considered as texts.

In short, we assume that AR has the ability to help create better understanding of the real body by the creation of an in situ ”illusion” of real lungs in a real body. As our study examines the subject-specific perspectives and usefulness of AR as a tool in the teaching and learning of respiratory processes in this light, the relevant themes arising out of the texts are: real respiration, visual whole, increased understanding through the use of 3D visual materials, in situ.

In the analysis of this subject-specific learning perspective in higher education, data is analyzed on the basis of Svein Sjøberg’s [16] theory of science education. He sees science learning as being placed where subject-specific knowledge and pedagogical reflection intersect. This is where the answers to the question of “How is science learned?” may be found as this area concerns itself with applying a constructivist approach to the use of images of the body to facilitate the learning of anatomy and physiology. [16]. This implies the recognition of an existing knowledge of the subject (anatomy and physiology), but the way in which it is understood involves the individual’s mental images and construct of the body as an entity. It is in this perspective that the students’ experiences with the AR app are analyzed: What did they see and discover about the lungs? How did it affect their mental construct? Which aspects attracted their attention? And which limitations did they see in the app?

As previously mentioned, understanding the workings of the lungs is very difficult, and the teaching usually takes place with students in quite passive roles and with visual aids that are static or fragmented in their nature – or both. Hence, we suspect that AR can help facilitate the learning processes through visualization of 3D-images in situ and through the activity that students are engaged in while working with the app. This is also in line with Sjøberg’s claim that an ideal teaching practice reflects the general view of learning as an active process where the individual constructs meaning based on previous experiences and through the challenges prepared by the teacher [16].

3.2 Results

From the data collected, it becomes clear that there are several advantages to be had from working with AR in the teaching and learning of anatomy and physiology. At the same time, however, students also noted limitations in the prototype app that was used.

3.2.1 AR as a helpful, new, supplementary tool

In terms of providing a new approach that is less centered around the traditional visual aids mentioned above, the AR experiment seems to have succeeded and students generally see the technology as helpful and promising[4]:

> *It would make the reading less ”heavy” as you get an immediate image of what the organs look like and how they work. Any extension [of the app to cover other areas] will be good; it is a really good idea and a good alternative tool for learning.*

> *To me, I would be able to use it as a reference book, and if I had the images before I read the text, I would be able to understand the topic much better.*

Thus these students see the AR visuals as a needed alternative learning tool, and it shows that students are aware of the need for new learning tools. However, students see it as a highly useful supplement to the textbook and as something to be used together with the textbook, not as a replacement. The perceived value becomes clear through interview statements like the following:

> *[…] it has given a good picture of what it looks like when we breathe and what the lungs look like – all that with the different lobes and so on. It was also nice that you could see that back of the lungs as that is rarely seen in the books.*

> *That the lungs actually changed color, I don’t remember that from what I read. Today, I have gotten an incredibly good picture of the lungs both in inspiration and expiration.*

We may assume that the traditional textbook materials can be supplemented substantially as a new dimension of the topic to be learned is added. From a constructivist point of view [16], knowledge is

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[4] All student quotations have been translated by the authors.

actively constructed. There may in the area of anatomy and physiology be exact knowledge that needs to be acquired. However, this knowledge is not sufficient as there is an active person involved in the knowledge construction: sensory impressions and stimuli do not just establish themselves in the mind as objective images of an external reality. Physical actions in and with the environment are what constitute the source of cognition [16].

Therefore, it is important when the students clearly express that the exploration of 3D in situ images contribute to an enhanced understanding. Through the observations of their actions and speech during the solving of the set IBSE tasks, it becomes clear that their work on constructing images appears to help them get a proper understanding of the workings of the lungs; just as it becomes clear that they seem to do this based on their individual needs for learning and on the basis of the knowledge and mental images that they already have.

3.2.2 Whole-body and in-situ advantages

In the evaluation, several students comment on the fact that the AR app provides a much more realistic image of the lungs than a textbook.

On the evaluation sheet, one student writes:

> *It gives a really good picture of how the body works. I hope it will be developed further so that it becomes possible to see the entire body and so that it can be connected to [a physical] body e.g. in terms of respiratory frequency.*

Thus students also want the progression in the knowledge acquisition that the app can support, e.g. through more knowledge of the interconnectedness between organs. They see the images that become available through AR as an important factor in their whole-body understanding in the subject of anatomy and physiology. Their focus is on the topic, and they seek out knowledge about the human body's structure and functions. Similarly, the videos clearly show their active engagement in trying to extract new information and build knowledge from the use of the app. There was a noticeable "wow factor" when the students first saw the images and their placement in a real body, and in the written evaluations, the students were quite explicit about the increased physiological understanding arising from this.

Figure 3: Lungs in situ through the iPad

Furthermore, one student writes:

> *I have gotten an image of what the lung looks like inside a body and how it changes when you breathe. Better understanding of dimensions, the size and placement of the lungs, seeing front and back. […] It has been illustrative to see the physiology and how the lungs change color. You now have an idea of their size […] and I now I know where they are placed and the differences in color that take place during respiration […]*

Other students express similar experiences and perceived effects. In addition, as can be seen from the work with the IBSE questions, students very much notice the color changes, color blotches and other anatomical characteristics of the lungs.

In terms of the degree to which the app presents real or realistic images and movements, students judge this as more illustrative than other apps they have previously worked with, e.g. VisibleBody[5], in terms of lung functionality, movement etc., and they largely ascribe this to the visual whole that is created through the use of the T-shirt and in situ placement. They report a major qualitative difference between seeing the lungs when a person with a T-shirt is involved, placing the lungs inside a real body, and accessing the same images via the printed tags placed on a table; the in situ placement thus seems to be of importance to the facilitation of learning.

3.2.3 Limitations

Students were quick to spot some of the limitations of the prototype app: Thus they noticed that the lungs were the same size no matter the size of the person wearing the T-shirt, which reflects the fact that the prototype was made to fit a 70-kilo body. It seems important that there is concord between what the app shows and the reality in which it is placed so that the app stays realistic and adapts in face of changes in its physical context.

Similarly, it is of course necessary that the app be dependable. One group of students described how the lungs started “shaking” or “vibrating” at one point, and this led them to wonder whether this was actually something that lungs do or whether it was a technical error.

In addition, the students commented on the fact that the AR app was only the *illusion* of the person breathing. However, the illusion was so powerful that it took a while for students to realize this. In their evaluations, they commented on the improvement that a connection to the actual person and the increased interactivity arising from this would provide:

> *If it can show the real person’s concrete breathing, it would be even more exciting to do various tests and see and understand even more of the physiology.*

Obviously, this is not possible at the moment, but an inclusion of data aligning the movements of the AR lungs with e.g. the respiratory rhythm of the person wearing the T-shirt is a realistic extension.

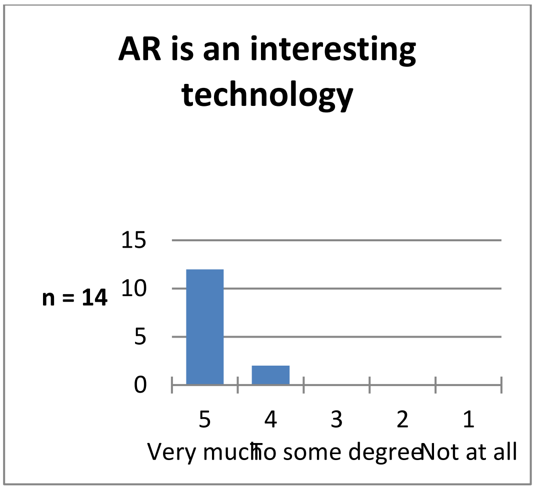
4 CONCLUSIONS AND PERSPECTIVES

4.1 Conclusions

On the basis of the above, it seems reasonable to conclude that our experiment shows how the use of AR does appear to have the potential to facilitate student learning and increase their level of understanding of the subject matter at hand.

In general, as appears from the quantitative data, students are also here positive and can see potential in the use of AR in their future education (figs. 3 and 4).

[5] A 3D anatomical model that may be manipulated



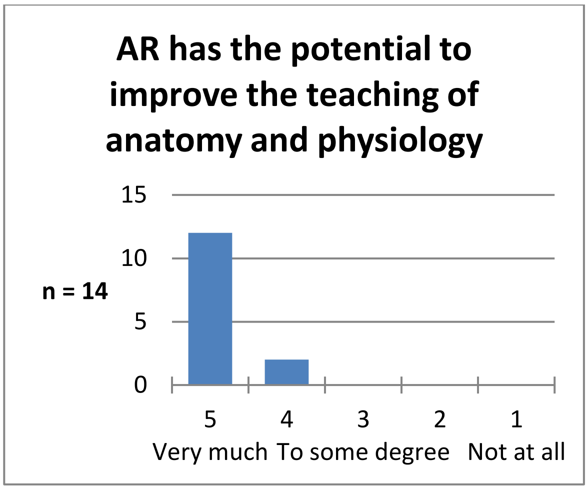


Figure 4: Student evaluation

Figure 5: Student views of AR potential

4.1.1 Increased understanding

Asked whether the use of the app had provided them with better understanding of the position and movement of the lungs, all students convincingly said yes, and in addition, they expressed enthusiasm about the use. We might assume that the perceived aid provided by the app as well as the enthusiasm involved can lead to higher motivation, which is, in turn, likely to facilitate learning.

From the interviews it is clear that the 3D in situ images provide the students with knowledge of the placement and position of the lungs inside the body and thus aids students in the adaptation of their already constructed mental image. This becomes evident from e.g. the following statements about AR:

> *It is really good in the context of anatomy and physiology as this subject is very difficult to understand – it could [generally in the subject] create better understanding of how things work when it can be visualized in this way.*

Similarly, also the observation of student interaction with the technology, student evaluations in general, and interviews all point to the use of this technology being helpful to their learning processes and understanding; and it certainly provides a new way of establishing a classroom with involved students that can actively engage and interact with the object they are learning about.

4.2 Perspectives for further research and development

After the testing of a simple proof-of-concept app in one context, it is obvious that more work needs to be done. This is true both in terms of more advanced technological development and in terms of subsequent research on the effects and potentials of the next generation of AR apps for the teaching of anatomy and physiology.

4.2.1 Student suggestions

As students had finished testing the simple app, they were also asked to comment on the appropriateness of the simple app and point to technical developments that would further increase their learning achievements and understanding of aspects of both the specific topic and the subject of anatomy and physiology in general. From their comments, it seems clear that – as expected – there is much potential for further development, and students point to the following:

- The app should be able to draw on and connect to respiration data from the person wearing the T-shirt so as to make possible the visualization of real-time breathing
- It should be possible to see the lungs from all angles
- The app should have layers so that it would be possible to add or activate a lung disease – e.g. emphysema or COLD[6] – to the visualization of the lungs in order to help the understanding of changes and effects

[6] Cronic Obstructive Lung Disease

- The relevance and need to have AR for many more parts of the body so that the understanding of the complex interactions and interdependencies between different organs is enhanced

4.2.2 Further research:

In this paper, we have described our first test of a proof-of-concept augmented reality app, which creates an illusion of seeing a person's lungs breathe within that person. We have discussed the app's potential as an educational object within the context of nursing education, we have elaborated on it being created in learner-centered perspective through an inquiry-based approach, and we have concluded that already as a proof-of-concept, according to the students, it furthers the understanding of lung anatomy and physiology. We have also shown that there is a lot of unused potential, which will require further development.

When the app is extended and expanded, whether it be to involve more data on the workings of a single organ or on several organs and their interconnectedness, more research into the actual effects of the uses of AR on student learning needs to be done. Aspects that might be explored are e.g. the relation between increased understanding and learning outcomes as perceived by students and the actual effects.

Furthermore, one might reasonably assume that some of our conclusions in this study may carry over to other subject areas, presumably especially in science subjects and other subject areas where intricate workings of systems are hidden and not easily illustrated and understood. This would also be a reasonable area to investigate further.

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