

POTENTIAL OF AUGMENTED REALITY IN SCIENCES EDUCATION A LITERATURE REVIEW

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Abstract

Fewer and fewer students in Europe choose STEM education while in today's job market have a growing need for people with such education. There are many reasons for this situation, but one important factor is that many students perceive school science as difficult. In science, there are many complex and abstract concepts to be learned, which puts high demands on students' abstraction capability. Augmented reality (AR) is a technology that show potential in regard to help students with among others things abstraction of science concepts.

AR expand / modify the user's perception of reality. Visual extension of reality is probably the best known, but it may also be in other forms such as sound.

Azuma et al.[1] definition of AR which are based on three characteristics:

- The combination of real and virtual objects in a real environment
- Runs interactively and in real time
- Compiles real and virtual objects with each other

Technology that can delivered AR content exists in many formats e.g. head worn devices, handheld devices and projection screens. Meta, Microsoft Hololens and Magic Leap's is three of a growing number of companies that currently develops advanced head worn devices for AR. While head worn AR is still too expensive for the classroom, handheld devices like smartphones and tablets already available in many classrooms and therefore easy to adopt.

The purpose of this article is to shed light on potential AR have in science education as presented in publications about AR for education in general and science education in particular.

In this Article four parent parameters that directly or indirectly may have a positive effect on learning outcome in science education is established: (1) cognitive effort, (2) Motivation; (3) Situated learning, (4) inquiry based learning.

Using visualization of models that are abstract and complex sciences concept, can make these concepts perceived less abstract and complex and thus help students. Visualization using AR in science can be done in many ways. AR can visualize in 3D, visualize the invisible, visualize alternative and multiple perspectives[2], [3], [4]. Situated learning has long been recognized as a good learning principle. Within AR game based AR learning mentioned as an example of situated learning. Using mobile phones in the AR game in which students play Environmental Detectives the game using GPS that provide students with information about where they are and let them find traces of environmental crimes[5]. Such situated learning arena can engage students in a deeper way than if they just read about environmental crime.

The AR-sci framework for planning, development and evaluation of AR resources for science education is one of several frameworks that are presented in this article.

Keywords: Augmented reality, science education.

1 INTRODUCTION

An increasingly smaller proportion of those who take higher education choose science[6]. Meanwhile, we live in a world where the need for such skills is growing[6].

Science is considered so important that all primary school students receive education in the subject. While the subject may be seen as a preparation for and recruitment to further education in science, the subject has also another dimension[7]. For although all students receive education within science the majority will not work in science. Education must also make students aware of how natural science knowledge is built and how it affects the world.

Regardless of how one felt about the two approaches to science education it is important that students learn the subject. When the number of applicants for science education is reduced, it may be an indication of their attitude to the subject.

Although Augmented reality (here after AR) as a technology have strengths and weaknesses like all others, this article will focus solely on the positive potential of AR and how it may facilitate science education.

Learning outcome either directly or indirectly is a main part of the research done in the area of AR in science. In this Article four parent parameters that directly or indirectly may have a positive effect on learning outcome in science education is established: (1) cognitive effort, (2) Motivation; (3) Situated learning, (4) inquiry based learning.

1.1 Challenges in science education

To meet the challenges associated with the students' perception of science and to get more people to choose an education in science there have been made several attempts to identify where the shoe pinches. How teaching in science are conducted is an element that are highlighted[6],[7]. Curriculum structure is also highlighted as a contributing cause [7].

In this article, the main topic is how AR can be a positive contribution to student's experience with science in school.

1.2 Augmented reality

1.2.1 What is AR

AR using technology to expand the user's perception of the real world. While AR can be used for expansion of different senses perception of the real world, there are currently expanding the visual perception of the real world which is most widespread. Pokémon Go is an AR games played on mobile devices such as smart phones. The game was released July 6, 2016, by September 8, the same year, Pokémon Go has been downloaded over 500 million times worldwide[8]. The user can access various items and options in the game based on where the person is in the real world. Actions carried out in the real world such as distance a user walked affects items in the game. Although Pokémon Go is not the first AR game, it is the first to have achieved such widespread use.

Availability of mobile devices such as smart phones and tablets has made AR available for the large masses. Smartphones are currently equipped with many sensors such as cameras, GPS, accelerometer and gyroscope. These sensors allow the smartphone to form a virtual perception of the real world and use this information to add an augmented layer of information on to the real world.

Azuma et al.[1] define AR based on the following three properties:

- a) combines real and virtual objects in a real environment
- b) runs interactively, and in real time
- c) aligns real and virtual objects with each other.

These three criteria may be illustrated using Pokémon Go as an example. a) the player can see the real world through the phone's camera, Pokémon's to be captured is a virtual 3D figure placed as a virtual layer over the image from the phone's camera. b) the player can interactively in real time try to capture Pokémon by "throwing" a virtual ball against the Pokémon that appear on screen. c) Pokémon is a virtual object that is align with the real world so that if the player turns the phone so the image from the real world changes, the virtual Pokémon appear as part of the real world and move accordingly.

1.2.2 AR technology

While the use of smartphones for AR makes the technology readily available to a large audience, it is limited in that the user sees the "real" world appears as an image on the screen so the user sees both the real world and the virtual objects all composed of pixels on a screen. Others solutions such as Microsoft HoloLens allows the user to see the real world through a transparent lens and that only the virtual object is projected in the lens thus appears as a part of the real world. Azuma et.al. differentiates AR technologies in the following three categories, (1) mobile devices, suchlike as Smartphone and Tablet, (2) stationary units and (3) head mounted display[1]. Mobile devices are

inexpensive and readily available in many areas, making it affordable to use the technology in schools. Head mounted display is rapidly developing and we should not ignore the fact that it eventually can become the preferred AR technology although there is currently a very expensive technology.

While the technology to display the AR content is important the tools for development of AR content must not be overlooked. In school contexts it clear that content production also will be an important element. Whether it is done by professional AR manufacturers or by teachers and students. Tools for producing AR content is available to the teachers and professional AR manufacturers. Tools from vendors, i.e. Layar, Wikitude Studio Aurasma Studio Junaio browser and Blippar allows users with different backgrounds get started with AR production.

1.2.3 Categorization of AR

Augmented Reality is often divided into marker-less or marker-based categories[9]. Pokémon Go is an example of Marker-less AR since it uses GPS data identify the user's location before overlaying virtual information. Marker-based AR, on the other hand, relies on visual markers, suchlike as QR codes. Another way to distinguish between categories of AR is location-based and image-based AR[10]. As image recognition technology improves, the need for predefined markers may disappear.

1.3 Research question

Which factors within augmented reality helps contributes to pupils' attitude towards, and learning in science education?

2 METHODOLOGY

To find answer to the research question first there was made a selection of the most relevant journals in the field. After the journals were identified, they were each searched for articles on the topic. For articles that were found in the search the abstracts were read to identify relevant articles. After the relevant articles were identified, the contents of the articles analysed and categorized. These findings were then analysed and discussed based on the challenges that are presented for science education in the introduction.

2.1 Selection of journals

To make a systematic search for the most relevant journals Google scholars h5-index was used. A search for journals was done in the category: Educational Technology. The top 5 journals selected for further search for relevant articles about augmented reality in education. Table 1 lists the five journals that were selected.

Table 1: list the five selected journals

	Journals	h5-index
1.	Computers & Education	88
2.	British Journal of Educational Technology	48
3.	The Internet and Higher Education	43
4.	Journal of Educational Technology & Society	41
5.	Journal of Computer Assisted Learning	40

2.2 Criteria for search in the journals

To make the selection of articles that was as relevant as possible, the following criteria was used when searching the journals:

- Articles published in the period 2006-2016.
- Articles with key word: Augmented reality.

- After initial search the abstract of all articles was read, article which are not related augmented reality although it was mentioned was removed from the list.

After searching and filtering the list consisted of 73 articles that are relevant to this article, see Table 2

Table 2: Number of articles in each of the journals

Journal	number of articles
Computers & Education	62
British Journal of Educational Technology	6
The Internet and Higher Education	0
Journal of Educational Technology & Society	2
Journal of Computer Assisted Learning	3
Total	73

2.3 Classification of parameters found in the articles

The selected articles were read in their entirety in order to identify any potential AR has for science education. More than 30 parameters relating to the potential for AR was identified in the articles. These parameters were then analysed for further and condensed to four parent parameters. The articles were also categorized as either: the testing of AR, review of research in the field, development framework.

3 RESULTS AND DISCUSSION

The background for most of the articles is either directly or indirectly about learning outcome and learning outcome are therefore not included as a separate parameter. Parameters related to the use of AR is therefore summarized in 4 parent parameters that directly or indirectly may have a positive effect on learning outcome in science education: (1) cognitive effort, (2) Motivation; (3) Situated learning, (4) inquiry based learning.

3.1 Four parameters of AR in science education

3.1.1 Cognitive Effort (here after CE)

Under this parameter we find elements like learning in 3D, see the unseen and Juxtaposing information.

Cognitive effort is about how the amount cognitive effort needed to solve a task could affect learning[11]. Students who perform calculations that require multiplication, may for example by having learned the multiplication tables by heart release cognitive capacity to other parts of the task.

Science is perceived by many as difficult and it often requires a high degree of abstraction [6]. AR may be used to reduce CE so that students can more easily see how different phenomena works. AR can help reduce CE in several ways. Wu et. al. has set up a list of five features of affordance in AR, juxtaposing information, learning in 3D and see the invisible are three of these. These three can help it to reduce students' cognitive effort to achieve understanding of a phenomenon[4].

For example, a virtual 3D model of a heart that pumps blood with juxtaposed information about the various parts enables the learner to quickly see how the various parts are interrelated and affect each other, which can give students more cognitive capacity to understand the circulatory system as a whole.

When one assembles a dresser from IKEA one will constantly switch between having your attention focused on either instructions or the dresser. Such switching may be regarded as increasing the cognitive load. Use of AR can let you see the instruction together with the physical object, which

makes it less of a need to switch focus between the two, which in turn contributes to reduced cognitive load[11].

It's not always about reducing cognitive effort. when CE is at the right level, students will have to use sufficient effort to understand how something are interconnected and thus learn better. Based on the example of 3D heart we can now imagine that the students have a 2D image of the heart. It's not necessarily as easy to see how it all fits together, which will require higher cognitive effort from student to understand the heart's function. This higher effort may possibly cause the student better remember how as heart valves function.

3.1.2 Motivation

Under this parameter we find elements like students increased involvement, and positive attitudes towards science.

Motivation is a large and varied disciplines, this article chose to use the following broad definition: "... an internal condition that causes, manages and maintains behaviour"[12].

Schunk and Zimmerman lists four ways motivation affects learning[13]. Motivated students are more attentive to their learning Processes. Motivated students who choose to do a task when given the opportunity shows greater progression. Motivated students make an extra effort to learn difficult tasks and achieve higher mastery. Students who are motivated experience greater satisfaction and positive Affect When given the opportunity two learn[13].

When students experience science as difficult is it even more important to maintain their motivation. Of the four categories of AR is Motivation is the factor most often mentioned in the articles.

In an experiment with the use of AR in conjunction with field trip teachers reported that students showed greater commitment and increased development of self-efficacy than traditional on field trips[14]. Another study compares the use of educational games with and without AR on iPhone, were scores on both games were equally regarding learning outcomes, but 90% of the student's state that they prefer AR game[15]. This shows that even though AR is still a young technology the students indicates it as motivational.

A study evaluating the use of AR in a visual art course concluded that motivation Attention and Satisfaction scored better than similar slide based courses[16]. further the study concludes with "As a result of our study, we conclude That the positive impact of AR on motivation leads students two achieve higher levels of engagement in learning activities with less cognitive effort."[16]

3.1.3 Situated learning

Under this parameter we find elements like sense of presence, Immersion, immediacy, cooperation, interaction and location.

Situated learning is about how learning is related to the specific environment and context in which learning takes place[17].

Several studies mentioned the value of that learning happens in an authentic context, either because it leads to increased commitment and motivation, deeper understanding or lead to cooperation between student's community of learners [18],[19],[20].

In a fieldtrip where AR was used students showed an increasing awareness about factors that had implications for how research is done and what the results mean[14].

in another study student who used AR to juxtapose Information under exploration by a botanical garden reported that AR did exploration more interesting[21]

3.1.4 Inquiry based learning(IBSE)

Under this parameter we find elements like Interaction and task.

One of the initiatives that are being highlighted is changing teaching from being deductive to be inquiry based[6]. Inquiry based teaching in science promotes students' curiosity and their interest in science[6]. In addition, it can also help to develop students' interpersonal skills and their ability to handle open-ended problems solving[6].

Tnova and Sibor describes IBSE follows:

It is an instructional learner-centred approach that on the bases of inquiry integrates theory and practice, and develops knowledge and skills for a solution to a defined problem. Students have to solve the problem, conduct self-directed learning and work in teams to make their own connection, creation and organization for future application in similar problems(s. 200) [22]

Study of using AR in IBSE have shown to achieve better resulted then traditional IBSE[19]. This can be explained by students is less exposed to cognitive overload when relevant information is presented in the right place at the right time during their studies[19]. Use of AR on fieldtrip can also support new pedagogy since the technology supports independence in students as they explore and learn on their own[14]. IBSE Also supported by the AR by allowing students carry out virtual experiments that would otherwise be too expensive or dangerous to do in real life[23].

3.1.5 Framework

In addition to the four categories there are also several articles that present different forms of framework for AR in education. These frameworks have different approaches, some are specific to the subject or context, while others are more general. Here is a brief description of tree of the frameworks that is about AR in education.

Wu et. al. has set up a list of five features of affordance in AR emphasizing that AR not only be looked at as a technology concept but also as a pedagogical concept.[4] The following is the five features of affordance in AR listed by Wu et. Al. : Learning content in 3D perspective, Ubiquitous, collaborative and situated learning, Learners' sense of presence, immediacy, and immersion, Visualizing the invisible, Bridging formal and informal learning.

Bujak et. al. present a framework of tree perspectives for understanding learning with AR[11]. In this framework Physical, cognitive and contextual are the dimensions used to analyse how AR is conducive to learning.

The AR-sci framework for planning, development and evaluation of AR resources for science education is a framework that looks at different pedagogical and technical elements in the use of AR as a part of science education[24]. The framework consists of the following 9 continua: Interactive, Creator, Collaborative, Situated learning, Inquiry based science, Real world augmentation, 3D visualization, Juxtaposing different perspectives, And Data Driven.

Common to most frameworks that look at AR in education is that they see AR as both a technical and pedagogical concept.

3.2 Need for further studies

Most studies covered in this article were of small groups and over a short time. Studies in larger scale should be undertaken to support the positive discoveries made so far.

4 CONCLUDING REMARKS

In this article it is presented four parameters for the use of AR in science education (1) cognitive effort, (2) Motivation; (3) Situated learning, (4) inquiry based learning. These four categories can be both directly and indirectly help to improve learning outcomes in science. Many of the items proposed here as potential in AR to promote science education is not limited to AR. IBSE is for example listed as an important measure to promote the subject independently of AR[6].

Although many of the studies address AR in education and they are limited in terms of both the number of informants and in time, they nevertheless show an interesting potential for support of science education.

AR is not a new concept, but it is only in recent years that the technologies have made it possible to apply it on a larger scale as a teaching tool. It makes AR still an immature and too little investigated teaching tools. Further research is therefore required to identify its potential better and confirm that the discoveries made so far also measure up to larger contexts.

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