Exploring the Learning Potentials of Augmented Reality Through Speculative Design

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Abstract. A state-of-the-art literature review pointed to the need for further investigation of augmented reality to broaden the understanding of the learning potentials of augmented reality. This paper presents an empirical study intended to bring insights into the learning potentials of augmented reality regarding both formal and informal learning using a speculative design process in online workshops with students from a K1–12 teacher education program. The empirical investigation consisted of five online workshops with a duration of 2.5 h and three to six participants per workshop. The theoretical frame of the study was speculative design workshop and John Dewey's theories. The paper explored two research questions: What are the learning potentials of augmented reality when explored by students from a K1–12 teacher education program using speculative design? Why and when is it relevant to explore the learning potentials of augmented reality, in such a way and how can it be done? The findings show that the learning potentials of augmented reality span different categories, such as supporting praxis, bridging the physical and virtual, use of different modalities and activities, supporting social practice, and extending communication e.g. across locations. Our findings further indicate that although speculating on the learning potentials of augmented reality is difficult, it can offer some insights that inform both the current state of a situation or topic and direct future inquiries in the field. However, the user's input does not always bring innovative insights and tends to be dependent on their existing knowledge and attitudes.

Keywords: Augmented reality · Speculative design · Immersive learning

1 Introduction

In the article "Augmented Reality and Virtual Reality in Education. Myth or Reality?," Elmqaddem (2019) argued that augmented reality (AR) has the potential to create change in the form of new teaching and learning methods. According to Garzon et al. (2019) regarding the systematic review of AR in educational settings, researchers should continue to conduct more studies on the inclusion of AR systems in teaching-learning processes. This empirical study materialized to address the clear need for knowledge about the learning potentials of AR, not only in connection with a specific technology but also to inform and guide the development of new technology using AR in learning situations. The research took its point of departure in a speculative design workshop

E. Brooks et al. (Eds.): DLI 2021, LNICST 435, pp. 156–163, 2022.
https://doi.org/10.1007/978-3-031-06675-7_12

(e.g., Auger 2013; Dunne and Raby 2013) in an online format using design tools such as storyboards to investigate and speculate about the learning potentials of AR.

Workshops can function as a research method that allows participants to acquire capabilities in and develop their own practice about that phenomena, as well as enable researchers to investigate the phenomena in question (Ørngreen and Levinsen 2017). In this study, the objective was to engage the participants, students from a K1–12 teacher education program (K1–12 students), in the process of speculating on the use of AR in educational settings for both formal and informal learning. Part of the K1–12 teacher education program is to acquire technological understanding in general and knowledge about the use of new technologies, such as AR. The K1–12 students were a relevant choice as participants because they are used to and able to think about learning situations and develop existing practices, and they could potentially become users of AR in an educational setting in the future. The project had a dual purpose: to investigate the learning potentials of AR in a broad formal/informal setting and to explore speculative design as a method where the participating K1–12 students could gain insight and knowledge on the use of AR in learning situations. This paper focuses on the use of innovative methods when exploring the learning potentials of AR. The aim of the study was to investigate the learning potentials of AR through a series of speculative design workshops that, through the use of reflective, dialogical and explorative design tools, such as storyboards, would engage the participants in a pragmatic exploration-based process. Two research questions guided this aim: What are the learning potentials of AR when explored by students from a K1–12 teacher education program using speculative design? Why and when is it relevant to explore the learning potentials of AR, in such a way and how can it be done?

Below, we provide information about the research design, which includes the definition of AR used in the project, brief theoretical insights, and a presentation of the data (Sects. 2.1, 2.2 and 2.3). These are followed by an analysis of the workshop data, including findings on the learning potentials of AR (Sects. 3 and 4). The paper ends with a discussion and conclusion (in Sects. 5 and 6), where the findings are discussed in relation to the second research question.

2 Research Design

The investigation had a participatory and design-oriented perspective, and the project's knowledge approach stemmed from pragmatism with an overall abductive approach through the research process. Due to the futuristic perspective of wanting to investigate and speculate about the learning potentials of AR, the research design took point of departure in a speculative design workshop (e.g., Auger 2013; Dunne and Raby 2013).

2.1 Definition of Augmented Reality

AR has its origin in 1957, when Morten Heilig invented the machine Sensorama, which was the first example of an immersive and multisensory experience (Sünger and Çankaya 2019). The machine used colors, scents, fans, sound, and a movable chair to create an immersive experience. In 1966, Ivan Sutherland and Bob Sproull created the

first head-mounted display, which, despite its limitations, could show the user a virtual layer of information on top of reality. Despite earlier inventions, it was not until 1992 that the concept of AR emerged, and it is attributed to Thomas Caudell and David Mizell at Boeing Company (Sünger and Çankaya 2019). In this period, AR moved from being multisensory to becoming a concept that describes how virtual information is layered on top of reality. The definition of AR used in this project was inspired both by the literature review and Wikipedia - in particular, the definition applied in the Concise Fintech Compendium by Patrick Scheuffel (2017) - expanded with the understanding of AR found in the immersive and multisensory experience that Morton Heilig created with the machine sensorama in 1957 (further described in Sünger and Çankaya 2019). The definition of AR used in this study is as follows:

Augmented reality is an interactive experience of the real and/or augmented world, where the experience of objects found in the real and/or augmented world is enhanced through augmented sensory stimuli. It can be across several sensory modalities, including visual, auditory (sound), haptic (feeling that one is touching or being touched) and somatosensory (experience of touch, pain, temperature, vibration), taste, and smell.

2.2 Speculative Design

According to Mitrović (2015), design has primarily been regarded as a problem-solving practice and is usually aimed at problems detected by professions such as economics and sociology. However, Dunne and Raby (2013) posited that when faced with complex problems, the designer has to act speculatively. Speculative design is an activity in which imagination or speculation is recognized as knowledge, and in which futuristic and alternative scenarios can convey ideas. Speculative design is about allowing all possible possibilities to be discussed and used to jointly define a preferable future for a given group of people, and not about predicting the future (Dunne and Raby 2013). More insights on speculative design as a method, and how it is used in this project, can be found in the article "Speculative Design as a Method of Inquiry in an Online Workshop Setting" (Hansen et al. 2021).

2.3 Data

The empirical data consisted of various data sources over a four-month period in 2020. A state-of-the-art literature review was conducted first to identify the learning potentials of AR. Then, with the intention of gaining deeper knowledge about learning situations and AR, two in-depth interviews were conducted with experts Lise Dissing Møller, Lector at KP, and Lucas Nygaard, Founder of Hololink. Lastly, five workshops with K1–12 students were held, with the purpose of investigating the use of AR in a learning situation, using a speculative method in an online setting. Each of the five workshops was 2.5 h in duration. The data consisted of audio recordings of the workshop sessions, 20 visual storyboards created by the K1–12 students and their written documentation of five creative exercises during the workshops, and observations and field notes written after the workshop. A thematic analysis of the workshops investigated the learning potentials of AR identified by the K1–12 students and visualized through storyboards.

3 Analysis

The analysis of the learning potentials of AR was based on the exercise materials and 20 storyboards created by the 20 K1–12 students in the online speculative design workshops, as well as transcripts and observation/field notes written after the workshop. In this analysis, a learning situation was understood as the framing of one or more tasks that scaffold the learners to achieve a desired knowledge or goal, and where the framing utilizes the different types of interactions that AR offers. The theoretical concepts developed by John Dewey were then discussed and developed into theoretical points of attention for analyzing AR learning situations such as broad activities, social praxis, context, and materials (as presented and discussed in, among others, Brinkmann 2007; Hickman 2016).
Theoretical points of attention in relation to AR:

- Broad activities - The learning situations with AR should be based on broad activities and tasks that incorporate many characteristics and competencies. They must lead to a real and workable result that gives rise to reflection and choices that can be translated and assessed in practice.
- Social practice - Learning situations with AR should be a joint activity or practice where the successes and failures of the joint activity are experienced as one's own.
- Context - Learning situations with AR should connect learning with the "common context" by incorporating everyday context in the form of home, school, community, and business.
- Materials - Learning situations with AR should include physical and augmented materials in the form of raw materials, loose parts, tools (both existing and the production of tools), and finished products. There must be an opportunity for interaction with the artifacts.

The analysis of the learning potentials of AR consisted of a deductive thematic analysis of the transcripts, storyboards, and exercise documents from the workshops. The first round of analysis searched for learning situations in the written empirical data, as it is in the learning situations that the learning potentials emerge.

The learning situations were then categorized based on the theoretical points of attention presented above and further grouped based on similarities. The second round of the analysis focused on the produced visualization from the participants in the form of storyboards. These were also categorized based on the theoretical points of attention presented above. The themes found in the two categorizations were then compiled into seven exemplary learning situations: "race with various tasks," "bridge to surroundings," "project work using the surroundings/city/context," "augmented teacher," "interaction with augmented materials," "use of geographical context," and "use of historical context." In the in-depth analysis, the theoretical points of attention were used to unfold how AR's learning potentials were expressed as they appeared in the teacher students' imagined learning situations.

As an example, the analysis of the storyboard below pointed to the need for an AR help function as well as indicated how AR can be used to provide information about the surroundings, in this case knowledge about physics principles (Fig. 1).

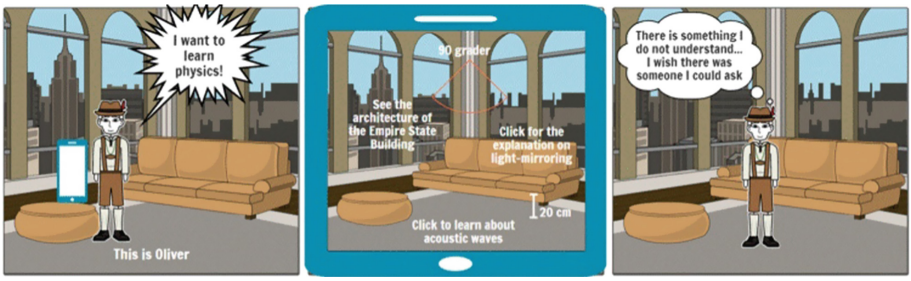

Fig. 1. A storyboard from the workshops (reproduced via www.storyboardthat.com and translated for anonymity)

Analysis of the participants' experience of the workshops showed that some K1–12 students engaged in the speculative process positively, while others were more reluctant. Being innovative in their approach became difficult for the participants due to lack of familiarity with AR and not understanding the technology completely. For example, knowing very little about AR and being critical toward technology in education in general, one participant became quite frustrated by the process but completed the speculative process and, at the end, commented positively on the structure and narrative of the workshop (Hansen et al. 2021).

4 Findings

Analysis of the data from the five speculative design workshops highlighted different categories of learning potentials of AR, which can be utilized in both formal and informal learning situations.

AR can support learning by relating to and supporting praxis

This learning potential is connected to the theoretical points of attention *context and social practice*. AR:

- provides opportunity for trying things out in praxis through a linking of home, school, society, and business.
- allows the learner to place themselves in an augmented context and thereby gain experience with the praxis reflected in that context and learn through praxis in contexts that would not otherwise be accessible due to distance, security issues, or contexts found only in the past.
- supports the learner via a help function in being critically reflective and exploratory.

AR can support learning by bridging the physical and virtual

In connection to the theoretical points of attention *materials and context*, AR:

- bridges the physical and virtual world by placing augmented artifacts in the environment, which adds knowledge to and about the physical context, expanding the interaction potential of the context.

- provides access to the distant and/or historical by creating augmented contexts, which offers the opportunity to explore and interact with the context.

AR can support learning by utilizing different modalities and activities
We associate this learning potential with the theoretical points of attention *context, materials, and broad activities*. In this view, AR can:

- to a greater extent, capture and represent more of life and reality, because placing augmented elements in a context provides increased opportunities and affordances for the use of modalities.
- point to knowledge outside the learning situation, where "online" becomes an extension of "offline," reflecting a greater capacity for facilitation of modalities.
- allow for active use of tools and artifacts.
- be based on "broad activities" that involve a coordination of many factors and combine several learning resources.

AR can support learning by supporting social practice and extending communication
This learning potential is connected to the theoretical points of attention *social practice, context, and materials*, in which AR:

- allows movement between and across locations, out of the classroom and into the immediate community, as AR can be used on mobile handheld devices.
- controls and supports the learning situation when the learning situation takes place in a context other than the school through its help function.
- supports and provides opportunities for social practice and gives learners an experience of being interconnected.
- expands the forms of communication between people due to its expanded ability to use modalities.

The findings do not add innovative insights into the learning potentials of AR; however, the investigation, together with the state-of-the-art literature review, points to a need for further research within the field.

5 Discussion

In the previous section (Sect. 2.2) the first research question was addressed. This section addresses the second research question: Why and when is it relevant to explore the learning potentials of AR in such a way and how can it be done?

In 2019, AR disappeared from Gartner's hype cycle of emerging technologies (Gartner 2019), and the author commented that "while continuing to be an important technology, Augmented Reality is rapidly approaching a much more mature state, which moves it off the emerging technology class of innovation profiles" (Skarredghost 2019). Gartners also predicted that "by 2021, at least one-third of enterprises will have deployed a multiexperience development platform to support mobile, web, conversational and augmented reality development" (Gartner, p. 4, 2020). It becomes important and relevant

to continue to explore the learning potentials of AR if the insights on the development of AR are combined with the need for more research on the use of AR in educational settings (Garzon et al. 2019) and the potential that AR has to create change in the form of new teaching and learning methods (Elmqaddem 2019). More studies are needed to demonstrate the effectiveness of the inclusion of AR systems in teaching–learning processes, according to Garzon (2019). Elmqaddem (p. 235, 2019) indicated that an "effective adaption of AR and VR in education and learning will not happen until some technical and social issues are resolved and education programs are more adapted to take full advantage of the potential of these technologies." This points to a need for using innovative approaches such as speculative design when conducting research aimed at informing the development of new technology using AR in educational settings.

This investigation had a participatory and design-oriented perspective that invited K1–12 students to participate in the investigation of the learning potentials of AR in a broad formal/informal setting. The findings from this investigation are not innovative or even new, which points to the fact that even though the K1–12 students were relevant as participants (see Sect. 1), they might not have the capacity to be innovative in the use of AR in educational settings, an exploration that requires continuous critical participation (Spinuzzi 2005). Design methods such as speculative design offer a way of exploring and investigating complex problems (Dunne and Raby 2013) and situations surrounding technology that do not yet exist (Ross 2017); however, the question of who the participants are becomes very important. One way of conducting a speculative design workshop could be with participants spanning different competencies and roles. This can add to the insights, the development of ideas, and perhaps increase the potential for innovation. However, in such a configuration of participants, there is a risk of people with certain knowledge or approaches taking over and dominating the process (Bødker 1998; Spinuzzi 2005; Bødker 2009). Another way is to utilize a longer timeframe so the participants iteratively can develop and expand their own understanding of the technology and the design process. This would allow for a process where the participants can try out and experience different applications of AR technology in educational settings and, based on this experience, further develop their ideas on AR. This approach requires time and resources that are not always available, and not all participants have the same capacity or inclination for creativity.

6 Conclusion

This investigation did not yield innovative new insights on the learning potentials of AR, although features that have not been reported in the state-of-the-art review of current applications were mentioned. Instead, it points to important considerations when using innovative methods in the investigation of the learning potentials of AR. Timeframe as well as choice of participants become essential considerations when choosing such an approach, as it was found that the user's input does not necessarily bring innovative insights, being dependent on their existing knowledge and attitudes. The literature highlights the need for further research in the field of using AR in educational settings, and the technological development of AR is progressing. This supports the need for innovative approaches to explore the learning potentials of AR and to inform and guide the

development of new technology using AR in learning situations as well as conducting more research on these topics.

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