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Interacting with augmented reality books through smart glasses: Affordances and advantages

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Abstract

The current study examined the perceived relative advantage of using smart glasses compared to using smartphones and tablets in order to interact with the content of augmented reality books. The sample consisted of 16 secondary education teachers of various subjects and 30 secondary education students, who interacted with augmented reality material in several schoolbooks' pages using the three aforementioned devices. The data were collected through semi-structured interviews based on the "relative advantage" variable of the Innovation Diffusion Theory. Data analysis showed that smart glasses are superior to other devices regarding the following affordances: hands-free access, first-person view, and sense of presence. Because of these affordances, there are certain advantages in teaching and learning such as greater concentration, increased motivation, enjoyment, pleasure, and interaction enhancement. The results have certain implications regarding the utilization of smart glasses and augmented reality books in education.

Keywords: Augmented reality books and smart glasses, Perceived relative advantage, Mobile technology devices, Teachers, Students

Introduction

Augmented Reality (AR) is one of several emerging technologies in education. The majority of research outcomes affirm that it can enhance student performance and increase their motivation and engagement in the learning process (Akçayır & Akçayır, 2017; Arici et al., 2019; Mazzuco et al., 2022). Image-based AR applications appear to be of particular research interest in recent years, one such example being AR books. These are printed books the pages of which are augmented and presented through use of digital content such as 3D objects, sound, and videos (Danaei et al., 2020). Viewing the augmented content is achieved through activation of a specific application on a computer or a mobile technology device. The added value of AR books lies in the presence of digital and virtual objects in the books' printed content and the real-time interaction with them. This results in the ability to access digital content and activities that contribute to the enhancement and better understanding of the static textual information and images of a book's page (Danaei et al., 2020).

In the near future, AR books are expected to be utilized in teaching and learning to a larger degree than they currently are. There are two reasons for this. The first one is the increasing number of commercial AR books with educational content. The second one is the increasing availability of easy-to-use AR development tools (Lytridis et al., 2018; Mota et al., 2018), through which the teachers themselves can create their own augmentations for the textbooks' units/modules that they teach. In this context, the research community has conducted a significant number of studies on AR books in education and the factors that affect their integration. These studies focus mostly on the books' design and formative evaluation (e.g., Martín-Gutiérrez et al., 2015; Corrêa, 2016), their impact on learning (e.g., Cheng & Tsai, 2014; 2016; Cheng, 2017) and the perceptions of pre-service (Koutromanos & Mavromatidou, 2021)

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and in-service teachers (Kazakou & Koutromanos, 2022) regarding the utilization of these books in their teaching.

A review of the literature reveals a research gap regarding which device provides a superior viewing experience of AR book content, and what relative advantage each device has compared to the others. Until today, the viewing of AR books was achieved mostly through use of smartphones and tablets. However, the advanced characteristics and upgraded affordances of modern wearable devices like AR smart glasses contribute to the development of an ideal platform for AR presentation in books. AR smart glasses differ from other devices in that they possess unique characteristics such as hands-free access, contextual information, sense of presence, immersion, and first-person view (Bower & Sturman, 2015). In the context of the Metaverse era, it is expected that progressively more schools will acquire augmented, virtual or mixed reality glasses. Hence, exploring the affordances and advantages of smart glasses as a means of viewing AR books compared to other devices (tablets, smartphones) can help the educational community to better utilize them in the future and provide students with optimized immersive experiences.

The purpose of the present study was to examine the perceived relative advantage of utilizing AR glasses to view augmented books compared to tablets and smartphones, according to teachers and students. The examination of the perceived relative advantage of smart glasses as a means of viewing AR books was based on the theoretical framework of the Innovation Diffusion Theory (IDT) (Rogers, 1996). According to this theory, a relative advantage is defined as the degree to which an innovation is better than its antecedent. In the current study, the perceived relative advantage is the degree to which teachers and students believe that AR smart glasses are superior to mobile technology devices (i.e., tablet and smartphone) in viewing AR books. The investigation of this factor in the context of the acceptance of a technology is of particular value, because the greater the perceived relative advantage of an innovation the faster the innovation will be adopted (Jeong, 2017). The investigation of the perceived relative advantage has been utilized in studies on both digital technologies (e.g., Swani, 2021) and, recently, on the impact it has on teachers' perceived usefulness in using AR applications in their teaching (Koutromanos & Mikropoulos 2021).

The current paper is structured as follows: the next section presents indicative results of the literature review regarding the affordances and advantages of using AR glasses and mobile devices in education. What follows are the sections of Methodology and Results. The paper closes with the Conclusions and Discussion section, which includes research limitations and suggestions for future research.

Related work

There is a lack of studies regarding the affordances of smart glasses in teaching and learning. The only related study is the one by Bower & Sturman (2015), which focuses on the affordances of two particular types of smart glasses, i.e., Google Glass and Oculus Rift. The sample they used consisted of 66 experts in educational technology topics from higher education institutions of various countries, who completed an online questionnaire. The experts who participated in the study perceive the following affordances of smart glasses: providing information in any context, ability to record information, ability to create scenarios which utilize simulation, and communication between students or between the students and the teacher. Furthermore, experts believe that smart glasses enable increased user engagement, direct view of an environment, on-site assistance by the teacher, and hands-free access. Moreover, further affordances of smart glasses recognized by experts include: seamless feedback, efficiency in teaching and learning, enhanced sense of presence,

distribution of educational resources, disconnection from the usual workplace, and gamification opportunities.

There are more studies on the affordances and advantages of mobile devices. For instance, Klopfer et al. (2002) developed and examined a simulation platform which utilizes AR and refers to environmental education, based on the affordances of mobile devices. According to the researchers, mobile devices have five characteristics which create pedagogical affordances. These are: (a) portability, thanks to which the user can go anywhere with the device, (b) social interaction, i.e., collaboration and face-to-face data exchange, (c) connectivity to other devices or one shared net, (d) context sensitivity, i.e., the ability to gather both real-life and simulated data within a certain environment, and (e) individuality, i.e., the opportunity for individual instructional support in the learning process (scaffolding).

Churchill & Churchill (2006) investigated the affordances of PDA technology by conducting a case study that lasted six months and included a technical education teacher. Their study revealed five affordances of PDA technology. These are: (a) access to multimedia resources or material, (b) opportunities for interconnection between users in the context of communicating, discussing, and exchanging ideas, (c) photographing, (d) representation of knowledge and ideas, and (e) the use of PDA as a tool for data analysis.

Song (2011) also studied PDAs, examining the factors which affect university students' perceptions regarding the affordances of PDAs as well as the way they are used in the context of their academic studies. The study lasted one year and included e-journals, artifacts created by students through PDAs, and interviews. According to the study's results, one of the affordances of PDAs is that they constitute tools for multimedia access and collection to facilitate learning through searching, deliberation, visualization, and development. Furthermore, PDAs can function as: communication tools, for learning through dialogue; connectivity tools, for learning through sharing; representation tools, for learning through visualization; and knowledge construction tools. Moreover, it was shown that PDAs are also regarded as tools of multiple use for various learning activities.

Cochrane & Bateman (2010) presented an overview of the pedagogical affordances of the integration of mobile Web 2.0 tools regarding smartphones when used in tertiary education. These affordances are based on a variety of activities that can be performed through smartphones: video streaming (i.e., real-time recording and distribution of events), Geo tagging (e.g., of photographs or events on a map), micro-blogging collaboration, Txt notifications (e.g., in lesson announcements), direct image and video blogging of ideas and events, mobile codes, enhanced student podcasts, and social networking, which can be achieved through collaboration in groups.

The literature review by Major et al. (2017) about the impact of tablet use in learning results examined the affordances of these devices, among other things. Most specifically, the researchers examined 33 studies that utilized tablets in schools and recorded four affordances which could possibly contribute to a positive impact of tablet use in learning. These are: (a) high degree of ease of use and the ability to incorporate various technical characteristics, such as camera or microphone, (b) easy configuration of the device, which supports inclusion, (c) touchscreen, which has an advantage over book pages regarding the representation of the information, and (d) availability and portability of tablets, which, when combined with immersive learning experiences, can contribute to situated and ubiquitous learning.

More recently, Tabuenca et al. (2021) examined the affordances of smartphones when used as "smart learning environments", conducting a literature review of 68 articles published from 2000 to 2019. According to the results of the review, smartphones are adaptable in the user's learning environment; traceable thanks to their various sensors; recommenders, i.e.,

they offer feedback and make recommendations based on already conducted learning activities; and pattern-recognizers, as they have the ability to recognize users' activity and behavior patterns. Furthermore, smartphones are also characterized as engaging, since they offer opportunities for personalized learning experiences; efficient regarding the performance and engagement; effective regarding learning; real-time interactive; and collaborative.

Methodology

The current study is qualitative and collected data through semi-structured interviews of secondary education teachers and students. It was conducted in May 2022 and all necessary protective measures against COVID-19 were taken during its preparation and conduction.

Sample

In the current study, 16 secondary education teachers (T1 to T16) and 30 secondary education students (S1 to S30) participated voluntarily. This sample came from two Senior High Schools (General Lyceums) in East Attica, Greece. The teacher sample consisted of 12 (75%) women and four (27%) men. Their average teaching experience was 15.8 years. Their areas of expertise were Greek Language and Philology (N=7), Mathematics (N=3), Natural Sciences (N=1), English Language and German Language (N=2), Informatics (N=2), and Economy (N=1). Out of the 16 teachers, eight were certified in Information and Communications Technology (ICT). However, 13 out of 16 teachers (81.25%) stated they use ICT in teaching.

The student sample consisted of 18 (60%) female and 12 (40%) male students. Out of them, 11 (36.67%) were first-grade students, 18 (60%) were second-grade students, and one (3.33%) was a third-grade student.

Data collection and processing

In order to examine teachers and students' perceptions regarding the relative advantage of using smart glasses for the utilization of AR books in their teaching and learning respectively, the study was conducted in three phases.

In Phase 1, the teachers attended –in groups of four– a presentation about the theoretical framework of Augmented Reality, AR books and smart glasses. More specifically, there was a presentation of their definitions, characteristics, and utilization possibilities in the educational process (duration: 45 min). In Phase 1, the students –also in groups of four– were informed about AR books and smart glasses. The characteristics of AR smart glasses were emphasized and their differences from Virtual Reality glasses were explained (duration: 30 min).

In Phase 2, the teachers in their schools' computer labs were familiarized with the use and affordances of the ZapWorks platform in order to be able to utilize AR for the development of their own AR pages in the schoolbooks they teach (duration: 1 hour). Also in Phase 2, teachers subsequently developed one or two AR pages in their schoolbooks. Afterwards, they viewed these pages with three different devices: smart glasses, tablet, and smartphone, via ZapWorks' Zappar application. The smart glasses device used was an Epson Moverio BT-300 pair of AR glasses (duration: 1 hour). In Phase 2, also in the computer lab, students wore the smart glasses and navigated through their various applications. Then, they projected augmented pages of their schoolbooks which had been created by the researchers of the current study. The augmented objects were images, videos, virtual tours, websites, and digital games. The augmented objects' educational content was on the subjects of History,

Mathematics, Biology, Physics, and Social sciences. The same pages were later projected through tablet and smartphone (duration: 1 hour).

In Phase 3, teachers and students participated separately in semi-structured interviews. The questions revolved around the topic "Which do you believe are the advantages of utilizing augmented reality books through the use of smart glasses compared to other mobile technology devices such as tablet and smartphone?" (duration: 20-30 min). This question aimed at investigating the perceived relative advantage which, as mentioned in the Introduction section, was based on the theoretical framework of the Innovation Diffusion Theory.

Analysis

To analyze qualitative data, thematic analysis (Creswell, 2012) was used. This means to identify, organize, and comprehend patterns of meaning contained within a data set (Braun & Clarke, 2012). It is divided into six stages: familiarization of the researcher with the research material, codification, search for themes, reviewing themes, definition and renaming of themes, and presentation of findings. Thematic analysis was conducted by two researchers of ICT in education.

Results

Out of the 16 teachers, 14 (N=87.5%) believed smart glasses were superior to tablets and smartphones regarding the projection of pages of AR books. Two teachers from the sample (N=12.5%) who mentioned they do not believe smart glasses have an advantage over the other mobile technology devices stated they prefer the tablet for the projection of augmented books. According to the first teacher, the tablet's larger screen makes it easier-to-use compared to the glasses, while the second teacher described looking through the smart glasses as tiring. All 30 students believed smart glasses are superior to tablets and smartphones.

According to the results following the analysis of the teachers and students' interviews, using smart glasses to interact with AR books is superior to using tablets and smartphones thanks to the smart glasses' unique affordances, namely hands-free access, first-person view, and sense of presence. These affordances, in turn, result in several advantages, such as greater concentration on the content of AR books, increased motivation, personalized learning, pleasure, and enjoyment. These results are presented in the following subsections.

Affordances

One of the unique affordances of utilizing AR books through smart glasses, as opposed to other mobile technology devices, mentioned by the 14 teachers and 30 students is hands-free access. According to them, this affordance leaves students with both hands free, which they can use in the meantime for any other book-related activity (e.g., turning pages, completing the books' exercises, etc.). One more affordance of smart glasses compared to other devices according to teachers and students is first-person view. This contributes to a better viewing of a book's augmented content; in other words, they have it right in front of them. Furthermore, they also regard the sense of presence as an important affordance. This is defined as the user's feeling of being "inside" the AR book's content. Table 1 presents indicative excerpts of the teachers and students' interviews regarding the affordances of smart glasses in their interaction with AR books.

Table 1. The affordances of smart glasses in the context of interacting with AR books

Affordances	Teachers	Students
Hands-free access	T3 "*The advantage is that you have your hands free.*" T8 "*The fact that you do not have to use your hands is the most important advantage.*"	S4 "*When I use the smartphone, I have to use my hands, which is tiring.*" S15 "*I wear the glasses, so I keep my hands free.*"
First-person view	T1 "*They are preferable because they offer a natural view. I mean, you have the book content before your eyes.*" T9 "*The content is in front of you… You can see what you need to see… Everything is within your field of view.*"	S6 "*Even though the glasses' screen is small, the books are before my eyes.*" S24 "*…they are superior because you do not have many devices around you nor do you need to turn from your screen to your book and vice versa. Everything is there before you.*"
Sense of presence	T10 "*With the glasses, I am inside the picture, inside the book content.*" T11 "*You feel you are part of what you see. There is a feeling of reality in which you belong.*" T12 "*With the glasses, students felt they were there, in the book. This differentiates them from the other devices.*"	S25 "*It is as if I am in it. We do not just see it, we live it. I feel what I see. While, with other devices, I just look.*" S28 "*Glasses are better in terms of directness, immediateness. I am already there, right inside the book.*"

Advantages in teaching and learning

The teachers and the students mentioned several advantages in viewing AR book content through smart glasses compared to tablets or smartphones. These advantages are presented in Table 2 alongside some indicative answers from the participants' interviews. Out of them, greater concentration, enjoyment, and pleasure are common in both samples. According to the teachers, students can remain concentrated on and engaged in the educational process much better than when using the other two devices. According to the teachers, this is thanks to first-person view and the sense of presence. The same advantage was also mentioned by the entirety of the students. They asserted that the other mobile devices would distract them, justifying it by saying that they are used to utilizing them in their leisure time, more for entertainment and communication applications and less for educational purposes. Therefore, they believe that using smartphones or tablets will lead them to open other apps like social media during the lesson, which will distract them from the AR books' content, while this will not be the case with the smart glasses. As for the advantages of enjoyment and pleasure, teachers mentioned they apply both to students and to themselves.

The rest of the advantages in Table 2 were mentioned only by teachers. One of them is students' increased motivation. Teachers believe that the affordances of smart glasses create an appealing environment of AR book content viewing, which contributes to the student's increased motivation to engage in it, compared to using other devices. One additional advantage of smart glasses over mobile devices is the opportunities it offers for personalized learning. According to the teachers, this means that the glasses can be utilized in a targeted way for each student (in specific activities or in a particular subject) so that each student can follow their own pace in learning.

Table 2. The advantages of using smart glasses in viewing AR books

Advantages	Teachers	Students
Greater concentration	T5 "*Students can concentrate more easily, each one on their own part.*" T16 "*Concentrating is easier with smart glasses. With other mobile devices, there is distraction.*" T16 "*If students wear smart glasses, they can fully concentrate, as opposed to when using other devices. Their attention is not distracted, because smart glasses help them concentrate on the book's content.*"	S1 "*Smart glasses do not encourage distractions. Mobile devices cause us to lose concentration because we access social media through them. I use smart glasses only for studying.*" S5 "*It is easier to concentrate with smart glasses and easier to be distracted with the other devices.*" S17 "*Smart glasses make me concentrate on what I see.*" S21 "*I will only have lesson-related applications in the smart glasses, which means greater attention to and concentration on the lesson. The smartphone tempts you to play with other apps; it can distract you.*"
Enjoyment	T10 "*Smart glasses make the educational procedure more appealing. My lesson will be more enjoyable.*" T1 "*AR viewing with smart glasses is a very entertaining experience. Even more so for younger ages.*"	S2 "*It is nicer and more enjoyable to be able to read and see through smart glasses.*" S1 "*If we wore smart glasses, studying would be a game. I mean, it is fun.*"
Pleasure	T4 "*The use of AR with the glasses was extremely pleasurable! It feels like an escape from the typical, everyday lesson.*" T5 "*AR via smart glasses was very pleasant. It seems like a technological world for students. The whole thing is very modern and harmonized with their interests. It is also pleasant for me, as I escape from the classic printed book pattern.*"	S4 "*It was more pleasing to scan AR with the smart glasses on.*" S12 "*I found it very pleasant that I could move with the smart glasses on without losing contact with the real-world environment. When I used other devices, it was harder…*"
Increased motivation	T12 "*The glasses provide greater motivation for students' participation, because they stimulate interest more than the other devices.*" T6 "*I believe that the projection of augmented objects in the books through smart glasses is a motive for students.*"	----------
Personalized learning	T6 "*If we can use them at will in a personalized way, e.g., for students who have not understood something, then they are superior.*" T16 "*Given that not all students have the same abilities, the same pace or even the same preferences in class, I believe smart glasses can contribute to what is called 'personalized learning'.*"	----------
Communication	T12 "*There is going to be greater interaction between the students because they will discuss about where they are*	----------

	and what they see. They offer opportunities for discussion, unlike other devices."	
Visualization	T11 "*When using smart glasses, all the senses are stimulated. It is a more experiential learning, i.e., a better learning.*" T5 "*Everything is more vivid through smart glasses. So, they can assist comprehension more than other devices.*"	----------
Interaction enhancement	T9 "*Students will participate even more in the procedure and interact better with the augmented objects if they use smart glasses instead of other devices.*" T16 "*Students are no longer passive participants. They can interact with what they see through the smart glasses. Projection through the glasses was more interactive compared to the smartphone or the tablet.*"	----------
Skill development efficiency	T4 "*…Using smart glasses in their study, students definitely acquire skills, such as text comprehension, mathematical and spatial skills.*" T7 "*Smart glasses change the students' role and make them more active. The students stop relying on me to find knowledge, they can find it by themselves. They have the opportunity to develop important skills, because the notion 'I learn how to learn' is promoted. This means they can search, discover, and have a better understanding of space and objects.*"	----------

One more advantage is communication. Teachers believe utilizing AR books through smart glasses will be a unique experience for students and will contribute to an enhanced communication between them in the context of discussing their experiences. The various visual stimuli which the smart glasses offer constitute one more advantage compared to other mobile devices. Thanks to them, the lesson is enriched, leading to a better understanding according to the teachers. The teachers also believe that smart glasses can contribute more effectively to the enhancement of students' participation and their interaction with augmented learning objects. Moreover, according to the teachers, the use of smart glasses by students can also enhance the development of various skills, such as spatial skills.

Conclusions and discussion

The purpose of the current study was to investigate the perceptions of secondary education teachers and students regarding the relative advantage of interacting with AR books through smart glasses compared to smartphones and tablets. Based on the analysis of the results, smart glasses are considered superior to the other two devices when used for viewing AR books. Their superiority lies in their unique affordances, which make them stand out from other

digital technologies. More specifically, these affordances are: hands-free access, first-person view, and sense of presence. These affordances are in accordance with previous studies that examined either the relative advantage or the affordances of wearable technologies and/or AR in education (Bower & Sturman, 2015; Koutromanos et al., 2020; Wu et al., 2014). Furthermore, this study revealed several advantages of AR smart glasses when used with AR books. According to the teachers, these advantages concern teaching and learning and derive from the affordances of smart glasses. Specifically, these advantages are greater concentration, enjoyment, pleasure, increased motivation, personalized learning, communication, visualization, interaction enhancement, and skill development efficiency. These are advantages corroborated by previous research literature about AR in education (Radu, 2014; Ibáñez & Delgado-Kloos, 2018; Koutromanos et al., 2020; Cai et al., 2022; Mazzuco et al., 2022). Therefore, the study's results confirm and enhance previous literature regarding wearable technologies and AR in education.

To the best of our knowledge, the current study is the first to examine the perceptions of in-service teachers and students regarding the utilization of AR books through smart glasses and mobile technology devices. Its results enhance the existing literature both on smart glasses in the field of education and on AR in teaching and learning. Moreover, these results provide certain implications. Education, among several other fields, is already gradually entering the Metaverse era. Smart glasses and AR books offer immersive experiences which can, in turn, bring added value to many subjects/disciplines compared to traditional teaching or other digital technologies. In order for teachers to fully comprehend new educational opportunities and the advantages of smart glasses and AR books, these technologies should be included in official educational policies. This can happen initially by providing the necessary infrastructure in school units (e.g., providing smart glasses and high-speed Internet connection). Meanwhile, the design of a pedagogical and technological teacher training program can be realized, so that teachers are able to create their own augmentations in their schoolbooks and integrate them effectively in teaching and learning.

The current study has two limitations. The first one is that the sample is convenient, as it consists only of students and teachers of secondary education. The second limitation is that only one particular smart glasses model was utilized (Epson Moverio BT-300). Possibly, the use of a different smart glasses model (e.g., Microsoft HoloLens 2) would give different results. While keeping in mind the aforementioned limitations, future studies could examine the perceived relative advantage of using AR books with smart glasses compared to smartphones and tablets in real-life learning conditions.

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