Creative Education, 2023, 14, 2777-2792
https://www.scirp.org/journal/ce
ISSN Online: 2151-4771
ISSN Print: 2151-4755

An Overview of Ten Years of Augmented Reality Smart Glasses in Education

Georgia Kazakou[1,2], George Koutromanos[1,2]

[1]Department of Primary Education, National and Kapodistrian University of Athens, Athens, Greece
[2]Hellenic Scientific Institute, Athens, Greece
Email: gkazakou@primedu.uoa.gr, koutro@primedu.uoa.gr

How to cite this paper: Kazakou, G., & Koutromanos, G. (2023). An Overview of Ten Years of Augmented Reality Smart Glasses in Education. *Creative Education, 14,* 2777-2792.
https://doi.org/10.4236/ce.2023.1413175

Received: November 1, 2023
Accepted: December 25, 2023
Published: December 28, 2023

Abstract

Augmented Reality Smart Glasses are an emerging technology that gains interest more and more among the research community. Their unique affordances such as the hands-free access and the transmition of first person view, differentiate them from other mobile and wearable technologies. The present study presents an overview of Augmented Reality Smart Glasses by emphasizing on the field of education. It includes the presentation of the affordances of AR and ARSG and the research activity on the effect of ARSG on education. Also, the factors that can influence their acceptance as well as students' views on viewing augmented books through glasses are presented. Finally, suggestions for future research in the field are made.

Keywords

Augmented Reality Smart Glasses, Overview, Education, Acceptance, Impact

1. Introduction

In recent years, there has been increased interest in the research community regarding the use of smart wearable technologies. This interest concerns various sectors, such as health (Iovanel et al., 2023; Aekanth & Tillinghast, 2023), wellness (Tikkanen et al., 2023), marketing (Bakhshian & Lee, 2023), and education (Al-Emran et al., 2023; Aranda-García et al., 2023). This interest is due to two factors: 1) smart wearable technologies can offer users many forms of human-computer interaction, as opposed to mobile devices (Stefana et al., 2021) and 2) smart wearable technologies are part of the Internet of Things (Ferreira et al., 2021), which is a technology that develops rapidly (Malhotra et al., 2021).

Smart glasses are a form of smart wearable technology that appeared on the market in 2013 when Google Glass was launched. The first definitions of smart

glasses were therefore related to this device. One of these definitions is by Aungst and Lewis (2015) who defined Google Glass as a wearable device like eyeglasses, except that Google Glass's technical interface essentially turns it into a computer interface. More recently, definitions of smart glasses have focused on the possibilities of interaction, applications, and virtual or augmented reality that they offer (Romare & Skar, 2020; Wei et al., 2018). Augmented reality smart glasses (ARSG) are becoming increasingly popular. Indicatively, in 2019, sales of ARSG amounted to 170 thousand units and are expected to increase to 3.9 million units by 2024, according to data from Statista (Alsop, 2022).

ARSG are significantly differentiated from mobile devices as they offer the user a more intense augmentation experience. This is because they enhance the immediacy, immersion, and presence of the user (Bower & Sturman, 2015). In addition, smart glasses have the hands-free feature and the ability to transmit the user's point of view (Bower & Sturman, 2015). These affordances led researchers to examine whether their use in the educational process has a positive effect on learning (e.g., Chen et al., 2023; Kuhn et al., 2016; Lukowicz et al., 2015) as well as explore their acceptance by teachers and students (e.g., AlHamad et al., 2021; Alfaisal et al., 2022; Aljanada et al., 2022; AL-Maroof et al., 2021; Kazakou & Koutromanos, 2022; Kazakou & Koutromanos, 2023).

The purpose of this study is an overview of the research literature on ARSG in the field of education as well as the highlighting of topics for future research in the field of smart glasses in education. More specifically, the research questions answered are:

1) What are the advantages and affordances of smart glasses for both students and teachers and the learning process?

2) What is their impact on formal and informal learning? and

3) What are the factors that can influence their acceptance and use by teachers?

The structure of this paper is as follows: first the advantages and affordances of augmented reality and ARSG are presented and then the research activity on the effect of ARSG on learning. Next, the factors that can influence the acceptance and use of ARSG by teachers and students are listed. Then, the topics for future research in the field of smart glasses in education are highlighted and finally the main conclusions are mentioned.

2. The Affordances of Augmented Reality and ARSG

Augmented reality (AR) is a new technology that is changing the way we see and experience the world and is part of so-called emerging technologies (Suh & Prophet, 2018; Verhulst et al., 2021). It adds digital elements to the real world, such as images, videos, text, three-dimensional objects, and sound. Early definitions of AR, such as that of Azuma (1997), precisely describe this superposition of digital assets in the real world. More recent definitions, however, such as that of Ibáñez et al. (2015), include the fact that the real and virtual worlds coexist, and the user can interact with the two worlds. Rauschnabel et al. (2022) defined

AR as an experience that merges in real-time the virtual content of a particular context with the physical world and therefore it is called hybrid.

AR has unique capabilities that make it a powerful educational technology. It can create immersive learning environments that combine digital and physical objects (Dunleavy et al., 2009). It can also help students understand abstract concepts (Arici et al., 2021) and present learning content from three-dimensional perspectives (Suh & Prophet, 2018). In addition, AR can facilitate learners' sense of presence, immediacy and immersion and visualization of invisible elements (Wu et al., 2013; Garzón et al., 2019) (**Figure 1**).

Marketing, medicine, entertainment, and education are some of the various fields that research has shown that AR has multiple benefits for users (Villagran-Vizcarra et al., 2023; Suh & Prophet, 2018). In education, the positive effects of AR include multiple cases. More specifically, it has been found that AR improves learning performance (Akçayır & Akçayır, 2017; Chang et al., 2022) and can enhance the motivation of students as well as it can increase their engagement (Sırakaya & Alsancak Sırakaya, 2022). Moreover, AR has been proven to improve students' professional skills such as assembly skills (Chiang et al., 2022), and cultivates their computational thinking (Theodoropoulos & Lepouras, 2021). In medical education, AR can be used to provide realistic and simulated learning experiences (Barsom et al., 2016). Especially in patient education, AR can help patients better understand their condition and follow their doctors' instructions (Urlings et al., 2022). In entertainment, AR can be used to create more immersive and educational experiences. That's because using AR games, the user experiences positive emotions such as excitement, pleasure, and curiosity (e.g., López-Faican & Jaen, 2020). Similarly, students who play AR games have better achievement and positive attitudes towards learning (Wu, 2021). Also, teenagers' use of AR games helps them have better relationships and increased attention and concentration (Ruiz-Ariza et al., 2018).

In recent years, AR has become more accessible to everyone thanks to technological advances in telecommunications and mobile devices (e.g., smartphones, tablets). However, viewing AR through mobile device screens is not as immersive and interactive (Holdack et al., 2022). ARSG are a new technology that incorporates a screen or projection system that displays digital information in the user's field of view (Bräker & Semmann, 2023). The glasses use sensors and cameras to track the movement of the wearer and the environment around them, creating a digital extension of the real world. This extension can include digital information, graphics, or virtual objects. Comparing ARSG with mobile devices, it is found that glasses provide a more immersive experience, which is related to two factors (Suh & Prophet, 2018): 1) the user's senses (sight, hearing, touch, movement) and 2) the constant stimuli that come from the user's interaction with the environment. Especially the possibility of immersion provided through glasses is very important for areas such as education, as it can transform the learning process into an experience that involves the whole body of the user (Buchem, 2019; Motti, 2019).

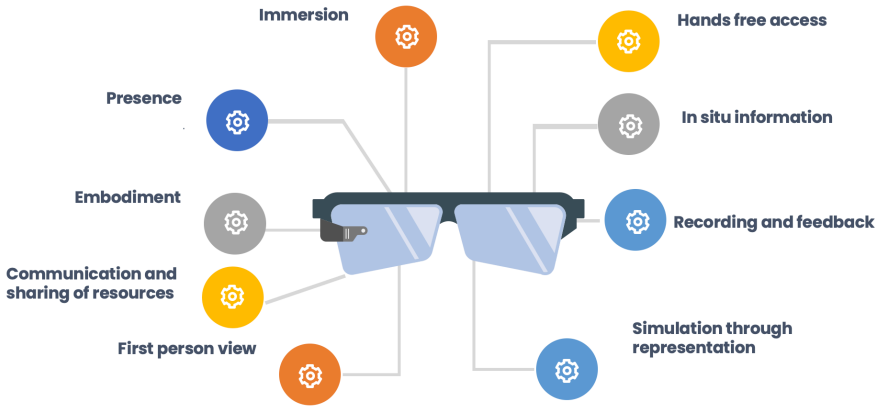

Figure 1. ARSG's affordances.

In addition, one of the first studies to explore the potential of smart glasses was that of Bower & Sturman (2015). The researchers used two eyewear devices, Google Glass and Oculus Fit, and recorded 14 of their affordances. These are the following possibilities: the hands-free access feature, first-person viewing, access to information while in place, communication and sharing of resources, recording and feedback, and finally simulation through representation. To sum up, thanks to their capabilities, ARSG outperform other augmented reality mobile devices in terms of user experiences, making them unique (Buchem, 2019; Holdack et al., 2022).

3. The Impact of ARSG on Formal and Informal Learning

According to the research literature regarding ARSG in an educational context, they have been more researched in medical education (Santana et al., 2021). In school education ARSG have been used in Science (Kuhn et al., 2016; Lukowicz et al., 2015), for learning English (Chen et al., 2023), in special education (Garzón, 2021) but also in the context of informal learning (Chen et al., 2023; Leue et al., 2015). The study of research activity regarding their use in the educational process shows that they have a positive effect on the educational process (Havard & Posiad, 2020; Koutromanos & Kazakou, 2020). Furthermore, it is considered that the enhanced educational environments used by smart glasses are superior to other augmented environments used by other mobile devices such as tablets, as the burden of cognitive load is lower and the enhancement of understanding is greater (Strzys et al., 2018).

This effect may relate to performance and to learners' motivations and attitudes. According to research, the effect on performance may refer to more effective and efficient learning and may be direct or indirect. For example, a direct positive effect on performance was recorded in the research of Lukowicz et al. (2015) where the experimental group, who wore Google Glass, performed better than the control group in execution, cognitive load, and curiosity of running physics experiments in high school. The indirect positive effect on learning occurs when teachers are the ones using the glasses. Specifically, glasses can pro-

vide teachers with real-time analytics about students' learning, metacognition, and behavior, which they can consider in order to design didactic interventions that will have a positive impact on learning, as for example was done in the research of Holstein et al. (2018).

ARSG also impact the performance of their users through the development or enhancement of new skills in both informal and formal learning. In the context of informal learning, one such case is the research of Leue et al. (2015). The sample was 22 visitors of an art gallery who reported that using Google Glass helped them boost their skills, such as how to learn about art on their own. Another study that confirmed the effectiveness of ARSG in developing skills in formal learning is that of Kopetz et al. (2019). The study concerned nursing students and examined how Google Glass can support nursing skills in nursing education (**Figure 2**).

Regarding the effect on students' motivation and attitudes, this may refer to interest in learning, orientation to inner goal, cognitive need, and increased curiosity about learning. One of the studies that found that ARSG are capable of increasing learning motivation is that of Chen et al. (2023). This research investigated the impact of incorporating smart glasses into an English-language dinosaur exhibition at the Natural Science Museum. In particular, the researchers found that ARSG outperform tablets in terms of motivation to learn.

In conclusion, research published on the effect of ARSG on teaching and learning shows that they have a positive effect on both formal and informal learning. However, this research activity is at an early stage and therefore more research should be done on how ARSG can be best used in the educational process. Some areas of research that could be a priority in the future for educational technology researchers are the design of appropriate applications for ARSG, best practices for the integration of ARSG in specific subjects and for the assessment of students as well as their theoretical framing with appropriate learning theories and teaching strategies.

4. The Factors of Acceptance and Use of ARSG in Education

It is well known that the successful integration of a new digital technology in the early stages of its diffusion can be facilitated by exploring its acceptance factors (Attié & Meyer-Waarden, 2022; Bao & Lee, 2023; Rahi et al., 2019). One of the issues that has concerned researchers of ARSG is that of their acceptance in the context of different fields of activity. According to the literature review of Koutromanos & Kazakou (2023) these sectors are commercial use, education, medical care, sports, and tourism.

Especially for the sector of education, research literature has shown that teachers' attitudes, beliefs, and perceptions play an important role in the adoption of new technology in teaching (Choi et al., 2023; Scherer et al., 2019). Therefore, it is important to record the factors of acceptance and use of ARSG by the stakeholders in education. So far, eight studies have been conducted on this topic.

Figure 2. A student viewing augented reality content with ARSG.

Four of these studies relate to higher education (AlHamad et al., 2021; Alfaisal et al., 2022; Aljanada et al., 2022; AL-Maroof et al., 2021) and focused on university students who would use glasses to improve their learning. This means that the students did not have the opportunity to use the glasses and answered the questionnaire without having the hands-on experience of the glasses. These studies utilized the theoretical framework of the Technology Acceptance Model (TAM) (Davis, 1989; Davis et al., 1989) which they expanded by adding new variables. The factors found to influence students' intention to use ARSG are functionality, trust and privacy, perceived ease of use and perceived usefulness (**Figure 3**).

The fifth study (Kazakou & Koutromanos, 2022) involved 91 in-service primary and secondary teachers who would use the ARSG to improve their teaching. This qualitative research was based on the TAM without giving the teachers the possibility to interact with the glasses. It was found that teachers intend to use smart ARSG in their teaching if they are convinced of their usefulness. The factors found likely to influence teachers in using the glasses are perceived usefulness, compatibility, facilitation conditions (i.e., technical and pedagogical training, provision of educational material, school infrastructure and equipment, support from educational leadership and financial ability to purchase glasses), the risk of privacy, and the potential risk to health.

The only study that used a sample who interacted with ARSG is that of Kazakou & Koutromanos (2024), which involved 45 primary and secondary school teachers. This research was based on MARAM (Koutromanos & Mikropoulos, 2021; Koutromanos et al., 2023; Mikropoulos et al., 2022) to which two variables (i.e., pleasure and social influence) of the Unified Theory of Acceptance and Use of Technology (UTAUT) were added (Venkatesh et al., 2003). In this study, teachers were found to be very positive about the use of ARSG and all variables measured were assessed positively by teachers. These variables were intention, attitudes, perceived utility, perceived ease of use, perceived relative advantage, facilitating conditions, enjoyment, self-efficacy, and social influence (**Figure 4**).

Figure 3. A teacher interacting with ARSG.

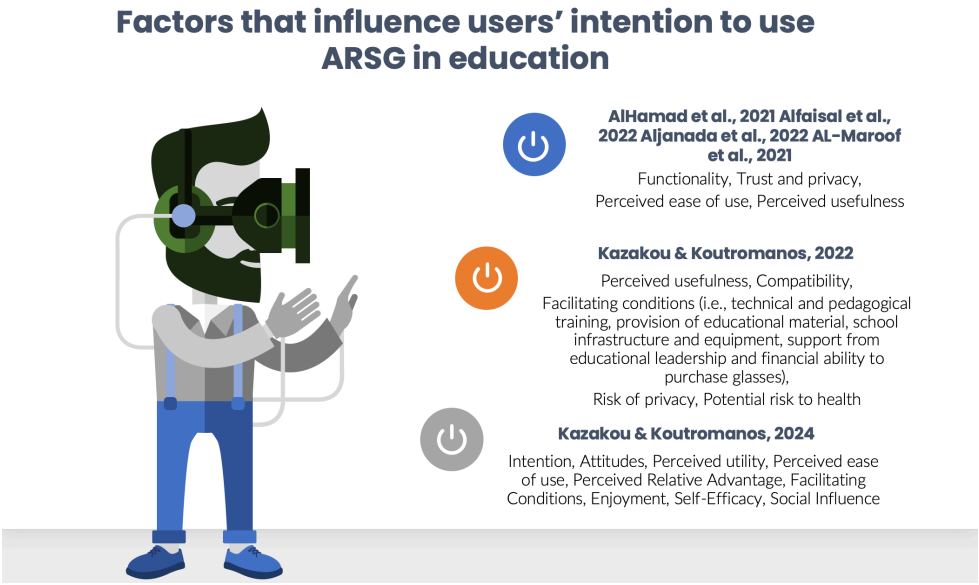

Figure 4. Factors that influence the intention to use ARSG in education.

One of the most important stakeholders in education is the student population. However, only two studies have been conducted to investigate students' acceptance and use of ARSG (Kazakou & Koutromanos, 2022; Koutromanos & Kazakou, 2023). These studies are presented in the next section.

What derives from the above is that the TAM is a reliable model for examining the acceptance and use of ARSGs as well. However, the factors investigated so far are limited in number and do not include the significant affordances of ARSG, such as immersion and presence. Especially for the education sector, research on acceptance and use factors should also include pedagogical factors (e.g., expected educational benefits, evaluation, quality of applications) based on other models and theories of technology acceptance besides the TAM.

5. Students' Views and Perceptions about ARSG

Although students are among the most important stakeholders in education,

they have not been included enough in studies related to the acceptance and use of ARSG. Only two studies have been conducted using a sample of students. The first one (Kazakou & Koutromanos, 2023) concerned 30 high school students and had a qualitative methodological design. From the thematic analysis of the interviews with the students, it was found that they perceive the use of ARSG in the educational process as pleasant, useful, and easy to use. They were also found to prefer them for viewing augmented textbooks over other mobile devices. **Table 1** presents in more detail the factors that can influence students to accept and use ARSG.

The second study (Koutromanos & Kazakou, 2022) also utilized 30 high school students and focused on students' perceptions of viewing augmented reality textbooks with ARSG. More specifically, the variable of Innovation Diffusion Theory (IDT) (Rogers, 1996), perceived relative advantage, was used to examine the potential relative advantage of glasses as a means of viewing augmented textbooks. The students projected augmented content of their textbooks through glasses, smartphones, and tablets. They then participated in semi-structured interviews, the thematic analysis of which led to the recording of specific technological characteristics and advantages for learning. According to the students, the technological features of ARSGs are hands-free access, first-person view, and sense of presence. These characteristics lead to specific pedagogical affordances which are greater concentration, enjoyment, and pleasure.

Table 1. Factors of acceptance and use of ARSG by students (Kazakou & Koutromanos, 2023).

Factors	Justification
Pleasure	1) They are an innovative technology. 2) They have technological and pedagogical affordances.
Usefulness	1) Are easy to use (immediate and easy access to information, relaxing and time-saving study). 2) They provide opportunities for a better understanding of knowledge, especially when combined with augmented textbooks (access to a larger, more modern, and remote piece of information, enrichment of textbooks with augmented subjects, attractiveness and motivation for learning, visualization of knowledge and experientiality). 3) They can solve practical problems related to the use of printed textbooks (unhindered access to textbooks and learning and ecological reasons).
Ease of use	1) ARSG are easy to use and learn. 2) Their applications are easy to use and learn.
Relative advantage	1) They have unique technological features (e.g., hands-free access, first-person view) 2) They have pedagogical advantages (e.g., greater concentration, enjoyment, pleasure, and sense of presence)

From the above, it is concluded that the research gap for the acceptance and use of ARSG by students is very large. It is important to note, however, that the research regarding students' adoption of ARSG, is very important because it can help teachers better assess the potential of this technology in the educational process. Therefore, further research is needed on the factors influencing students' acceptance and use of ARSG, which could take into account students' age and class, learning style and personal interest in technology.

6. Future Research on ARSG

ARSG can be combined with other technologies to enhance their capabilities and uses. One of these is artificial intelligence (AI) which can be harnessed in various ways to improve teaching and learning (Crompton & Burke, 2023; Zhang & Aslan, 2021). More specifically, AI can be used to personalize the learning experience. That is, to be used to monitor a student's progress and identify areas in which they need more support. ARSG can then be used to provide targeted teaching and feedback. AI can also be used to make learning more interactive and engaging, for example by creating simulations and augmented reality games to be projected through glasses. Another use of AI could be to adapt the augmented reality learning experience to the individual needs of each student. For example, AI can be used to adjust the difficulty level of augmented reality tasks or provide different types of feedback through glasses for student performance in real time.

Another technology that could be combined with ARSG is that of biometrics. Biometrics are unique physical or behavioral traits that can be used to identify individuals (Payne et al., 2023). Some common biometric features include fingerprints, facial recognition, and iris recognition. The combination of biometrics with ARSG in educational research can be done in a variety of ways. For example, ARSG equipped with biometric sensors can be used to monitor students' engagement and attention levels. This information can then be used to improve the design of augmented reality learning experiences and to identify students who may need additional support.

Biometrics can then be used in combination with glasses to provide personalized feedback. For example, ARSGs could be used to monitor a student's eye movements and head position to see how well the student understands the material presented. This information could then be used to provide the student with real-time feedback and support.

Another use of ARSG in combination with biometrics is to assess students' learning in a more objective and reliable way. For example, these glasses could be used to monitor a student's heart rate and GSR to measure their emotional commitment and cognitive load. This information could then be used to create more effective assessments and identify students who may be struggling.

By combining both artificial intelligence and biometrics with ARSG, education researchers can gain new insights into how students learn and develop.

These are technologies with enormous potential but still at an early stage of development and research. Therefore, future research on ARSG should take these technologies into account.

7. Conclusion

The present study presented a general overview of ARSG in the field of education. It included the presentation of the affordances of AR and ARSG, research activity on the effect of glasses on education and the factors that can influence their acceptance, students' views on viewing augmented books through glasses as well as suggestions for future research in the field.

Clearly, thanks to their affordances, ARSG offer users unique experiences. These in turn can bring added value to many subjects compared to traditional teaching or other digital technologies. Therefore, these technologies should be included in formal educational policies, and this means that two things are required: 1) specific infrastructure in schools and 2) the design of a pedagogical and technological training program for teachers. Greater acceptance by teachers will lead to more effective integration of this technology into the educational process.

Furthermore, the study of research activity on the effect of glasses on learning showed that the results are encouraging. If we consider the affordances of ARSG combined with the many advantages of AR in the educational process, we conclude that this technology has the potential to add value to education. There is, however, still wide scope for research on the effect of glasses on learning. In particular, these investigations could include 1) the study of the effects of glasses on students' motivation and performance at all levels of education, 2) the investigation of the impact of glasses on different learning styles, 3) the development of new methods for assessing students' learning with the use of glasses and 4) the formulation of a pedagogical framework for the use of ARSG in the educational process.

Regarding the factors that can influence the acceptance and use of ARSG, they are mainly based on the TAM. The factors investigated so far are limited in number and do not include the affordances of ARSG such as immersion, presence, and interaction. Future research should therefore consider incorporating additional factors/variables based on models and theories of technology acceptance other than the TAM. The research activity should include the variables of the framework Technological Pedagogical Content Knowledge—TPACK (Mishra & Koehler, 2006) in order to investigate their possible effect on the acceptance and use of ARSG, as has been done in other research on different technologies (e.g., Mayer & Girwidz, 2019; Yang et al., 2021).

Regarding research activity for students and the use of ARSG, it is obvious that there is a huge research gap. Some of the topics that could be researched are the factors of acceptance and use of ARSG by students, taking into account their age and class, their learning style and familiarity with technology, as well as their user experience and feasibility of ARSG.

To sum up, ARSG are a promising new technology for education. They have the potential to bring about changes in the way students learn, providing them with interactive and immersive experiences. For this reason, more research should be done on how best to use them in the educational process. The need for more research on ARSG in education is imperative and can be combined with other modern technologies. Thanks to this research, we will be able to develop the knowledge and tools we need to use this technology more effectively for all students.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Aekanth, S. G., & Tillinghast, D. J. (2023). The Emergence of Wearable Technologies in Healthcare: A Systematic Review. In V. G. Duffy, M. Ziefle, P. L. P. Rau, & M. M. Tseng (Eds.), *Human-Automation Interaction* (pp. 43-59). Springer. https://doi.org/10.1007/978-3-031-10788-7_3

Akçayır, M., & Akçayır, G. (2017). Advantages and Challenges Associated with Augmented Reality for Education: A Systematic Review of the Literature. *Educational Research Review, 20,* 1-11. https://doi.org/10.1016/j.edurev.2016.11.002

Al-Emran, M., Al-Nuaimi, M. N., Arpaci, I., Al-Sharafi, M. A., & Anthony Jnr., B. (2023). Towards a Wearable Education: Understanding the Determinants Affecting Students' Adoption of Wearable Technologies Using Machine Learning Algorithms. *Education and Information Technologies, 28,* 2727-2746. https://doi.org/10.1007/s10639-022-11294-z

Alfaisal, R., Alhumaid, K., Alnazzawi, N., Samra, R. A., Aburayya, A., Salloum, S., Shaalan, K., Al Khasoneh, O., & Monem, A. A. (2022). Predicting the Intention to Use Google Glass in the Educational Projects: A Hybrid SEM-ML Approach. *Academy of Strategic Management Journal, 21,* 1-13.

AlHamad, A. Q. M., Akour, I., Alshurideh, M., Al-Hamad, A. Q., Al Kurdi, B., & Alzoubi, H. (2021). Predicting the Intention to Use Google Glass: A Comparative Approach Using Machine Learning Models and PLS-SEM. *International Journal of Data and Network Science, 5,* 311-320. https://doi.org/10.5267/j.ijdns.2021.6.002

Aljanada, R., Abukhalil, G., Alfaisal, A. M., & Alfaisal, R. (2022). Adoption of Google Glass Technology: PLS-SEM and Machine Learning Analysis. *International Journal of Advances in Applied Computational Intelligence (IJAACI), 1,* 8-22. https://doi.org/10.54216/IJAACI.010101

Al-Maroof, R. A., Alfaisal, A. M., & Salloum, S. A. (2021). Google Glass Adoption in the Educational Environment: A Case Study in the Gulf Area. *Education and Information Technologies, 26,* 2477-2500. https://doi.org/10.1007/s10639-020-10367-1

Alsop, T. (2022). *AR Glasses Unit Sales Worldwide 2019-2024.* Statista. https://www.statista.com/statistics/610496/smart-ar-glasses-shipments-worldwide/#statisticContainer

Aranda-García, S., Otero-Agra, M., Fernández-Méndez, F., Herrera-Pedroviejo, E., Darné, M., Barcala-Furelos, R., & Rodríguez-Núñez, A. (2023). Augmented Reality Training in Basic Life Support with the Help of Smart Glasses. A Pilot Study. *Resuscitation Plus,*

14, Article 100391. https://doi.org/10.1016/j.resplu.2023.100391

Arici, F., Yilmaz, R. M., & Yilmaz, M. (2021). Affordances of Augmented Reality Technology for Science Education: Views of Secondary School Students and Science Teachers. *Human Behavior and Emerging Technologies, 3,* 1153-1171. https://doi.org/10.1002/hbe2.310

Attié, E., & Meyer-Waarden, L. (2022). The Acceptance and Usage of Smart Connected Objects According to Adoption Stages: An Enhanced Technology Acceptance Model Integrating the Diffusion of Innovation, Uses and Gratification and Privacy Calculus Theories. *Technological Forecasting and Social Change, 176,* Article 121485. https://doi.org/10.1016/j.techfore.2022.121485

Aungst, T. D., & Lewis, T. L. (2015). Potential Uses of Wearable Technology in Medicine: Lessons Learnt from Google Glass. *International Journal Clinical Practice, 69,* 1179-1183. https://doi.org/10.1111/ijcp.12688

Azuma, R. T. (1997). A Survey of Augmented Reality. *Presence: Teleoperators & Virtual Environments, 6,* 355-385. https://doi.org/10.1162/pres.1997.6.4.355

Bakhshian, S., & Lee, Y. A. (2023). Influence of Extrinsic and Intrinsic Attributes on Consumers' Attitude and Intention of Using Wearable Technology. *International Journal of Human-Computer Interaction, 39,* 562-574. https://doi.org/10.1080/10447318.2022.2041904

Bao, H., & Lee, E. W. (2023). Examining the Antecedents and Health Outcomes of Health Apps and Wearables Use: An Integration of the Technology Acceptance Model and Communication Inequality. *Behaviour & Information Technology,* 1-22. https://doi.org/10.1080/0144929X.2023.2183062

Barsom, E. Z., Graafland, M., & Schijven, M. P. (2016). Systematic Review on the Effectiveness of Augmented Reality Applications in Medical Training. *Surgical Endoscopy, 30,* 4174-4183. https://doi.org/10.1007/s00464-016-4800-6

Bower, M., & Sturman, D. (2015). What Are the Educational Affordances of Wearable Technologies? *Computers & Education, 88,* 343-353. https://doi.org/10.1016/j.compedu.2015.07.013

Bräker, J., & Semmann, M. (2023). Is There More than Pokémon Go?—Exploring the State of Research on Causal Modeling in the Field of Augmented Reality. *56th Hawaii International Conference Proceedings on System Sciences,* 1323-1332. https://hd.handle.net/10125/102793

Buchem, I. (2019). Design Principles for Wearable Enhanced Embodied Learning of Movement. In *Proceedings of Learning and Collaboration Technologies. Ubiquitous and Virtual Environments for Learning and Collaboration: 6th International Conference, LCT 2019* (pp. 13-25). Springer International Publishing. https://doi.org/10.1007/978-3-030-21817-1_2

Chang, H. Y., Binali, T., Liang, J. C., Chiou, G. L., Cheng, K. H., Lee, S. W. Y., & Tsai, C. C. (2022). Ten Years of Augmented Reality in Education: A Meta-Analysis of (Quasi-)Experimental Studies to Investigate the Impact. *Computers & Education, 191,* Article 104641. https://doi.org/10.1016/j.compedu.2022.104641

Chen, H. R., Lin, W. S., Hsu, T. Y., Lin, T. C., & Chen, N. S. (2023). Applying Smart Glasses in Situated Exploration for Learning English in a National Science Museum. *IEEE Transactions on Learning Technologies, 16,* 820-830. https://doi.org/10.1109/TLT.2023.3276702

Chiang, F. K., Shang, X., & Qiao, L. (2022). Augmented Reality in Vocational Training: A Systematic Review of Research and Applications. *Computers in Human Behavior, 129,* Article 107125. https://doi.org/10.1016/j.chb.2021.107125

Choi, S., Jang, Y., & Kim, H. (2023). Influence of Pedagogical Beliefs and Perceived Trust on Teachers' Acceptance of Educational Artificial Intelligence Tools. *International Journal of Human-Computer Interaction, 39,* 910-922. https://doi.org/10.1080/10447318.2022.2049145

Crompton, H., & Burke, D. (2023). Artificial Intelligence in Higher Education: The State of the Field. *International Journal of Educational Technology in Higher Education, 20,* Article No. 22. https://doi.org/10.1186/s41239-023-00392-8

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly, 13,* 319-340. https://doi.org/10.2307/249008

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science, 35,* 982-1003. https://www.jstor.org/stable/2632151 https://doi.org/10.1287/mnsc.35.8.982

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and Limitations of Immersive Participatory Augmented Reality Simulations for Teaching and Learning. *Journal of Science Education and Technology, 18,* 7-22. https://doi.org/10.1007/s10956-008-9119-1

Ferreira, J. J., Fernandes, C. I., Rammal, H. G., & Veiga, P. M. (2021). Wearable Technology and Consumer Interaction: A Systematic Review and Research Agenda. *Computers in Human Behavior, 118,* Article 106710. https://doi.org/10.1016/j.chb.2021.106710

Garzón, J. (2021). An Overview of Twenty-Five Years of Augmented Reality in Education. *Multimodal Technologies and Interaction, 5,* Article 37. https://doi.org/10.3390/mti5070037

Garzón, J., Pavón, J., & Baldiris, S. (2019). Systematic Review and Meta-Analysis of Augmented Reality in Educational Settings. *Virtual Reality, 23,* 447-459. https://doi.org/10.1007/s10055-019-00379-9

Havard, B., & Podsiad, M. (2020). A Meta-Analysis of Wearables Research in Educational Settings Published 2016-2019. *Educational Technology Research and Development, 68,* 1829-1854. https://doi.org/10.1007/s11423-020-09789-y

Holdack, E., Lurie-Stoyanov, K., & Fromme, H. F. (2022). The Role of Perceived Enjoyment and Perceived Informativeness in Assessing the Acceptance of AR Wearables. *Journal of Retailing and Consumer Services, 65,* Article 102259. https://doi.org/10.1016/j.jretconser.2020.102259

Holstein, K., McLaren, B. M., & Aleven, V. (2018). Student Learning Benefits of a Mixed-Reality Teacher Awareness Tool in AI-Enhanced Classrooms. In C. Penstein Rosé et al. (Eds.), *Artificial Intelligence in Education. AIED 2018. Lecture Notes in Computer Science* (pp. 154-168). Springer International Publishing. https://doi.org/10.1007/978-3-319-93843-1_12

Ibáñez, M., Di-Serio, Á., Villarán-Molina, D., & Delgado-Kloos, C. (2015). Augmented Reality-Based Simulators as Discovery Learning Tools: An Empirical Study. *IEEE Transactions on Education, 58,* 208-213. https://doi.org/10.1109/TE.2014.2379712

Iovanel, G., Ayers, D., & Zheng, H. (2023). The Role of Wearable Technology in Measuring and Supporting Patient Outcomes Following Total Joint Replacement: Review of the Literature. *JMIR Perioperative Medicine, 6,* E39396. https://doi.org/10.2196/39396

Kazakou, G., & Koutromanos, G. (2022). Augmented Reality Smart Glasses in Education: Teachers' Perceptions Regarding the Factors that Influence Their Use in the Classroom. In M. E. Auer, & T. Tsiatsos (Eds.), *New Realities, Mobile Systems and Applications. IMCL 2021. Lecture Notes in Networks and Systems* (pp. 145-155). Springer International Publishing. https://doi.org/10.1007/978-3-030-96296-8_14

Kazakou, G., & Koutromanos, G. (2023). Augmented Reality Smart Glasses: Why Do Students Prefer to Use Them in Learning? In T. Bratitsis (Ed.), *Research on E-Learning and ICT in Education* (pp. 137-154). Springer International Publishing. https://doi.org/10.1007/978-3-031-34291-2_8

Kazakou, G., & Koutromanos, G. (2024). Teachers' Perceptions towards the Use of Augmented Reality Smart Glasses in Their Teaching. In M. L. Bourguet, J. M. Krüger, D. Pedrosa, A. Dengel, A. Peña-Rios, & J. Richter (Eds.), *Immersive Learning Research Network. iLRN 2023. Communications in Computer and Information Science* (pp. 124-137). Springer. https://doi.org/10.1007/978-3-031-47328-9_9

Kopetz, J. P., Wessel, D., & Jochems, N. (2019). User-Centered Development of Smart Glasses Support for Skills Training in Nursing Education. *i-com, 18,* 287-299. https://doi.org/10.1515/icom-2018-0043

Koutromanos, G., & Kazakou, G. (2020). The Use of Smart Wearables in Primary and Secondary Education: A Systematic Review. *Themes in eLearning, 33,* 33-53.

Koutromanos, G., & Kazakou, G. (2022). Interacting with Augmented Reality Books through Smart Glasses: Affordances and Advantages. In *Conference of the Hellenic Scientific Association of Information & Communication Technologies in Education* (pp. 55-66).

Koutromanos, G., & Kazakou, G. (2023). Augmented Reality Smart Glasses Use and Acceptance: A Literature Review. *Computers & Education: X Reality, 2,* E100028. https://doi.org/10.1016/j.cexr.2023.100028

Koutromanos, G., & Mikropoulos, T. A. (2021). Mobile Augmented Reality Applications in Teaching: A Proposed Technology Acceptance Model. In *2021 7th International Conference of the Immersive Learning Research Network (iLRN)* (pp. 1-8). IEEE. https://doi.org/10.23919/iLRN52045.2021.9459343

Koutromanos, G., Mikropoulos, T. A., Mavridis, D., & Christogiannis, C. (2023). The Mobile Augmented Reality Acceptance Model for Teachers and Future Teachers. *Education and Information Technologies,* 1-39.

Kuhn, J., Lukowicz, P., Hirth, M., Poxrucker, A., Weppner, J., & Younas, J. (2016). gPhysics—Using Smart Glasses for Head-Centered, Context-Aware Learning in Physics Experiments. *IEEE Transactions on Learning Technologies, 9,* 304-317. https://doi.org/10.1109/TLT.2016.2554115

Leue, M. C., Jung, T., & tom Dieck, D. (2015). Google Glass Augmented Reality: Generic Learning Outcomes for Art Galleries. In I. Tussyadiah, & A. Inversini (Eds.), *Information and Communication Technologies in Tourism 2015* (pp. 463-476). Springer International Publishing. https://doi.org/10.1007/978-3-319-14343-9_34

López-Faican, L., & Jaen, J. (2020). EmoFindAR: Evaluation of a Mobile Multiplayer Augmented Reality Game for Primary School Children. *Computers & Education, 149,* Article 103814. https://doi.org/10.1016/j.compedu.2020.103814

Lukowicz, P., Poxrucker, A., Weppner, J., Bischke, B., Kuhn, J., & Hirth, M. (2015). Glass-Physics: Using Google Glass to Support High School Physics Experiments. In *Proceedings of the 2015 ACM International Symposium on Wearable Computers (ISWC'15)* (pp. 151-154). Association for Computing Machinery. https://doi.org/10.1145/2802083.2808407

Malhotra, P., Singh, Y., Anand, P., Bangotra, D. K., Singh, P. K., & Hong, W.-C. (2021). Internet of Things: Evolution, Concerns and Security Challenges. *Sensors, 21,* Article 1809. https://doi.org/10.3390/s21051809

Mayer, P., & Girwidz, R. (2019). Physics Teachers' Acceptance of Multimedia Applications—Adaptation of the Technology Acceptance Model to Investigate the Influence of

TPACK on Physics Teachers' Acceptance Behavior of Multimedia Applications. *Frontiers in Education, 4,* Article 73. https://doi.org/10.3389/feduc.2019.00073

Mikropoulos, T. A., Delimitros, M., & Koutromanos, G. (2022). Investigating the Mobile Augmented Reality Acceptance Model with Pre-Service Teachers. In *2022 8th International Conference of the Immersive Learning Research Network (iLRN)* (pp. 1-8). IEEE. https://doi.org/10.23919/iLRN55037.2022.9815972

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record, 108,* 1017-1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Motti, V. G. (2019). Wearable Technologies in Education: A Design Space. In P. Zaphiris, & A. Ioannou (Eds.), *Learning and Collaboration Technologies. Ubiquitous and Virtual Environments for Learning and Collaboration. HCII 2019. Lecture Notes in Computer Science* (pp. 55-67). Springer International Publishing. https://doi.org/10.1007/978-3-030-21817-1_5

Payne, R., Martin, B. A., Tuzovic, S., & Wang, S. (2023). Defining Biometrics with Privacy and Benefits: A Research Agenda. *Australasian Marketing Journal, 31,* 294-302. https://doi.org/10.1177/14413582231167645

Rahi, S., Ghani, M. A., & Ngah, A. H. (2019). Integration of Unified Theory of Acceptance and Use of Technology in Internet Banking Adoption Setting: Evidence from Pakistan. *Technology in Society, 58,* Article 101120. https://doi.org/10.1016/j.techsoc.2019.03.003

Rauschnabel, P. A., Felix, R., Hinsch, C., Shahab, H., & Alt, F. (2022). What Is XR? Towards a Framework for Augmented and Virtual Reality. *Computers in Human Behavior, 133,* Article 107289. https://doi.org/10.1016/j.chb.2022.107289

Rogers, E. M. (1996). *Diffusion of Innovations* (4th ed.). Free Press.

Romare, C., & Skär, L. (2020). Smart Glasses for Caring Situations in Complex Care Environments: Scoping Review. *JMIR mHealth and uHealth, 8,* Article e16055. https://doi.org/10.2196/16055

Ruiz-Ariza, A., Casuso, R. A., Suarez-Manzano, S., & Martínez-López, E. J. (2018). Effect of Augmented Reality Game Pokémon GO on Cognitive Performance and Emotional Intelligence in Adolescent Young. *Computers & Education, 116,* 49-63. https://doi.org/10.1016/j.compedu.2017.09.002

Santana, R., Rossi, G., Méndez, G. G., Rodríguez, A., & Cajas, V. (2021). Smart Glasses User Experience in STEM Students: A Systematic Mapping Study. InÁ. Rocha, H. Adeli, G. Dzemyda, F. Moreira, & A. M. Ramalho Correia (Eds.), *Trends and Applications in Information Systems and Technologies. WorldCIST 2021. Advances in Intelligent Systems and Computing* (pp. 455-467). Springer. https://doi.org/10.1007/978-3-030-72657-7_44

Scherer, R., Siddiq, F., & Tondeur, J. (2019). The Technology Acceptance Model (TAM): A Meta-Analytic Structural Equation Modeling Approach to Explaining Teachers' Adoption of Digital Technology in Education. *Computers & Education, 128,* 13-35. https://doi.org/10.1016/j.compedu.2018.09.009

Sırakaya, M., & Alsancak Sırakaya, D. (2022). Augmented Reality in STEM Education: A Systematic Review. *Interactive Learning Environments, 30,* 1556-1569. https://doi.org/10.1080/10494820.2020.1722713

Stefana, E., Marciano, F., Rossi, D., Cocca, P., & Tomasoni, G. (2021). Wearable Devices for Ergonomics: A Systematic Literature Review. *Sensors, 21,* Article 777. https://doi.org/10.3390/s21030777

Strzys, M. P., Kapp, S., Thees, M., Klein, P., Lukowicz, P., Knierim, P. et al. (2018). Phys-

ics holo.lab Learning Experience: Using Smartglasses for Augmented Reality Labwork to Foster the Concepts of Heat Conduction. *European Journal of Physics, 39,* Article e035703. https://doi.org/10.1088/1361-6404/aaa8fb

Suh, A., & Prophet, J. (2018). The State of Immersive Technology Research: A Literature Analysis. *Computers in Human Behavior, 86,* 77-90. https://doi.org/10.1016/j.chb.2018.04.019

Theodoropoulos, A., & Lepouras, G. (2021). Augmented Reality and Programming Education: A Systematic Review. *International Journal of Child-Computer Interaction, 30,* Article 100335. https://doi.org/10.1016/j.ijcci.2021.100335

Tikkanen, H., Heinonen, K., & Ravald, A. (2023). Smart Wearable Technologies as Resources for Consumer Agency in Well-Being. *Journal of Interactive Marketing, 58,* 136-150. https://doi.org/10.1177/10949968221143351

Urlings, J., Sezer, S., Ter Laan, M., Bartels, R., Maal, T., Boogaarts, J., & Henssen, D. (2022). The Role and Effectiveness of Augmented Reality in Patient Education: A Systematic Review of the Literature. *Patient Education and Counselling, 105,* 1917-1927. https://doi.org/10.1016/j.pec.2022.03.005

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly, 27,* 425-478. https://doi.org/10.2307/30036540

Verhulst, I., Woods, A., Whittaker, L., Bennett, J., & Dalton, P. (2021). Do VR and AR Versions of an Immersive Cultural Experience Engender Different User Experiences? *Computers in Human Behavior, 125,* Article 106951. https://doi.org/10.1016/j.chb.2021.106951

Villagran-Vizcarra, D. C., Luviano-Cruz, D., Pérez-Domínguez, L. A., Méndez-González, L. C., & Garcia-Luna, F. (2023). Applications Analyses, Challenges and Development of Augmented Reality in Education, Industry, Marketing, Medicine, and Entertainment. *Applied Sciences, 13,* Article 2766. https://doi.org/10.3390/app13052766

Wei, N., Dougherty, B., Myers, A., & Badawy, S. (2018). Using Google Glass in Surgical Settings: Systematic Review. *JMIR mHealth and uHealth, 6,* e54. https://doi.org/10.2196/mhealth.9409

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current Status, Opportunities and Challenges of Augmented Reality in Education. *Computers & Education, 62,* 41-49. https://doi.org/10.1016/j.compedu.2012.10.024

Wu, M. H. (2021). The Applications and Effects of Learning English through Augmented Reality: A Case Study of Pokémon Go. *Computer Assisted Language Learning, 34,* 778-812. https://doi.org/10.1080/09588221.2019.1642211

Yang, J., Wang, Q., Wang, J., Huang, M., & Ma, Y. (2021). A Study of K-12 Teachers' TPACK on the Technology Acceptance of E-Schoolbag. *Interactive Learning Environments, 29,* 1062-1075. https://doi.org/10.1080/10494820.2019.1627560

Zhang, K., & Aslan, A. B. (2021). AI Technologies for Education: Recent Research & Future Directions. *Computers and Education: Artificial Intelligence, 2,* Article 100025. https://doi.org/10.1016/j.caeai.2021.100025