International Society of the Learning Sciences

Teachers' use of augmented reality in the classroom: reasons, practices, and needs

Josef Buchner*, Jule M. Krüger*, Daniel Bodemer, Michael Kerres
josef.buchner@uni-due.de, jule.krueger@uni-due.de, bodemer@uni-due.de, michael.kerres@uni-due.de
University of Duisburg-Essen
*These authors contributed equally to this work

Abstract: Research on augmented reality (AR) in education shows various advantages and challenges for learners while research on teachers is scarce. In practice, teachers drive the implementation of AR in classes, and it is important to examine current practices and requirements to be able to effectively support their efforts. $N = 16$ teachers who had used AR in their classes took part in a survey with open-ended questions focusing on reasons for, current practice of, and needs when using AR in education. The answers were classified into different (sub-)categories. As reasons for usage, different instructional and non-instructional purposes are mentioned. In the current practices various technologies, design-platforms and educational materials are described, and needs include content availability, pedagogical integration, and technical infrastructure. The results are discussed with a focus on unexpected outcomes and the potentials of collaboration between researchers, practitioners, and other stakeholders to support teachers AR classroom integration.

Introduction

In this study, we examine teachers' use of augmented reality (AR) in the classroom. AR is an emerging visualization technology defined by the simultaneous presence of real and virtual objects that are geometrically aligned and enable real-time interactions (Azuma et al., 2001). Previous research identified several opportunities of AR for the purpose of teaching and learning. For example, AR can support the understanding of complex science concepts by visualizing the invisible (Yoon & Wang, 2014), scaffolds inquiry-based learning (Kyza & Georgiou, 2019), and reduces cognitive load leading to increased performance (Buchner et al., 2022). Krüger et al. (2019) describe three major characteristics that distinguish AR learning environments from other technology-enhanced learning scenarios and entail advantages when purposefully implementing AR for appropriate learning goals: *contextuality*, i.e. placing virtual elements in a real-world context; *interactivity*, i.e. combined physical and virtual manipulation; and *spatiality*, i.e. spatial positioning and dimensionality of virtual objects. In addition to promoting learning and comprehension, researchers mention motivational and affective factors as central outcomes when using AR in education (Akçayır & Akçayır, 2017; Ibáñez & Delgado-Kloos, 2018). However, along with the opportunities, research shows that implementing AR in the classroom is challenging. Most often, technical issues are reported in the literature, like the lack of devices, weak internet connection or problems during the representation of the AR visualization (Akçayır & Akçayır, 2017). Another matter concerns instructional design, including the identification of learning objectives that can be effectively achieved using AR or the prerequisites for learners to successfully engage with the AR learning environment. In their review, Buchner et al. (2022) distinguished between declarative and procedural knowledge acquisition and found that AR is better suited to promote procedural knowledge.

As the research presented shows, scholars have so far focused their investigations on learning and the role of the learners. Research that focuses on teachers is scarce. However, as for any other technology, teachers have a key role here as they are responsible for an effective and efficient use of the technology, like AR, in class. Alalwan et al. (2020) provide in their study a developing country perspective of AR usage in science education. The authors interviewed 29 primary school teachers revealing that lack of competency and resources (among others) were common challenges. In da Silva et al. (2018), results from Brazilian teachers and their use and experience with AR are reported. The authors conclude that AR is still something new for the teachers and a major limitation for further use of AR in school is the lack of content creation tools. Other studies exploring the AR experience of teachers under real classroom conditions are lacking. Hence, several questions regarding the use of AR in schooling remain open. For example, do teachers use AR in their lesson for the same reasons found in the research literature, which specific implementations do they use, and is the lack of resources also true for the European context? In this study, we aim to address these questions and contribute to the limited research base regarding teachers' use in educational practice. Therefore, we investigate teachers' reasons for and current practice of using AR in their classes. Furthermore, we examine what teachers require to overcome challenges linked to the usage of AR in education and to make the use of AR in practice more effective and efficient.

Methods

A semi-structured survey was addressed to German-speaking teachers who had used AR in education. A convenience sampling approach was used and $N = 16$ teachers, age 26 to 56 ($M = 37.80$, $SD = 8.74$), from different school forms and course areas took part. Six were male, nine female, and one did not disclose.

Five open-ended questions should trigger word-based, open responses in three categories, inquiring about teachers' reasons to use AR, their current practice of implementation, and their requirements to overcome challenges they come across. We added different sub-questions to elicit elaborate, detailed answers, for example specifying the question on how AR was used by asking for the specific methods and technologies and triggering a description of requirements by asking for what went wrong in the implementation. The specific questions in their original German and translated English form can be found here: https://osf.io/yqux4/.

The teachers were contacted especially through posts and messages on Twitter directed towards relevant audiences. A link to the online questionnaire was provided and participants gave their consent for data collection at the beginning. They then answered general questions about the context of their AR use. On the next page, the open-ended questions were given. At the end, the demographics were inquired, and a short debriefing was given.

Because the goal of the survey was to learn more about teachers' reasons to use AR, their current practice of implementation, and their requirements to overcome challenges they come across, these categories were also focused during data analysis when classifying the participants' answers. The authors classified answers and individual text-snippets into the three question-categories: (1) "Why do teachers use AR in instruction?"; (2) "How do teachers use AR in instruction?"; (3) "What do teachers need to overcome challenges of using AR in instruction?". Further, in a joint negotiation of two authors, answer-categories and -subcategories were developed.

Results and Discussion

The structure of the established categories will be described in more detail in this section. For example quotes per (sub-)category, see https://osf.io/yqux4/.

Why do teachers use AR in instruction?

Regarding the question why teachers use AR in their lessons, we found that most of the statements address a kind of instructional purpose with the sub-categories learning from AR, learning with AR, and learning about AR. Most of the teachers stated that they use AR to visualize content and invisible phenomena. As a result, the teachers expect the visualization to more effectively support comprehension of the content compared to other illustrations, e.g., 2D pictures (learning from AR). The use of AR to visualize the invisible is also reflected in the research literature on AR in education and the opportunity to illustrate complex and abstract content and information is described as a main benefit of AR usage. The possible advantage of 3D (like used in AR applications) over 2D is also reported by teachers in da Silva et al. (2018). The next most frequently mentioned instructional purpose represents a learning with AR perspective. Here, teachers used AR technology to involve the learners in a design process. For example, teachers reported that the students created videos to orally practice a foreign language. As shown in the literature, involving learners in a design process can be an effective learning approach. In the Brazilian context (da Silva et al., 2018) teachers also described AR content creation by students. In the developing countries perspective reflected in Alalwan et al. (2020) this purpose is missing because of lacking authoring tools. AR was also mentioned as a purpose on its own, representing a learning about AR perspective. For example, one teacher used AR in computer science education showing the learners how the technology works. Interestingly, this aspect is novel for our study. However, researchers point out the importance of learning about new digital technologies like AR due to an increasing demand for people with skills in this area (Fominykh et al., 2020).

We identified three categories not fitting into the instructional purpose category. Teachers implemented AR in the classroom because they themselves were interested in the technology and wanted to test it. Others mentioned that they wanted to design a learning experience beyond the curriculum to create memorable events for the learners. Another aspect concerned sustainability. One teacher stated that AR helps to provide further information without printing masses of paper sheets. While personal interest and providing experience beyond the curriculum is mentioned similarly in da Silva et al. (2018) and Alalwan et al. (2020), using AR for sustainable reasons is an aspect not reported in the literature so far. Another interesting result of our study is that none of the teachers quoted motivational aspects as a reason for AR use. This is contrary to the literature as authors indicate motivation as an important advantage of using AR in educational settings (Akçayır & Akçayır, 2017).

How do teachers use AR in instruction?

The questions of how teachers used AR in their lessons including which technologies and materials they implemented were answered very differently. The answers could be classified into three categories, namely

instructional approaches, technologies, and educational materials used. The instructional approaches mentioned in or implied from the description of the procedures include teacher-led approaches like demonstration and augmentation of available physical curricular materials. This is supported by the often-mentioned instructional purposes of illustration or concrete visualization of material in the previous section (Yoon & Wang, 2014). Further, student-centered instructional approaches were described, including inquiry, project-based and problem-based learning, and collaborative experimentation. Inquiry, project-based and collaborative learning were described as important approaches that can be achieved with AR (Garzón et al., 2020), which may be a reason the teachers used them. The implementation of the student-centered approach of design-based learning is furthermore connected to the above-mentioned instructional purpose of learning with AR instead of from AR.

Concerning the different technologies used, a distinction can be made between hardware and software, or more specifically design-platforms used. Most teachers stated that they used mobile devices like tablets and smartphones, which are ubiquitous and less expensive than the less-mentioned AR-glasses. One teacher described projecting the screen of a tablet onto a beamer, probably to enable every student to see the material. This shows that creative approaches can be born if, for example, there are not enough devices available. Many different design-platforms were mentioned, including Areeka Studio, Blippar and HP Reveal, which was also mentioned in da Silva et al. (2018). While this diversity in available and used software may be enriching because different use cases can be addressed, the incompatibility between different platforms might be a problem for sharing materials. Many of the teachers mentioned more than one platform, which shows that they either had to switch due to different use cases, or that they switched because they have not found the perfect platform, yet. Either way, there seems to be some effort involved in choosing the appropriate application.

Concerning educational materials, some of the participants describe materials that they developed themselves, while other participants described having used available materials. Own materials were often developed with easily usable authoring tools like HP Reveal or Blippar, although more elaborate content-creation including the design of a booklet and a specific application were also mentioned by a participant. The educational material that was already available could be split into the marker-based, marker-less, and location-based AR technologies, where marker-based materials were described more often, e.g., in the form of Areeka animal cards or the MergeCube. A few marker-less materials, like GeoGebra, were mentioned. Location-based material was described only in one case, namely with the platform Actionbound. This prevalence towards marker-based materials may be based on their higher availability due to less technological requirements for devices. While marker-less applications require a device that can scan surfaces which is, for example, possible through ARkit and ARcore technologies in most new IOS and Android mobile devices, marker-based applications mostly only need a functioning camera for target detection.

What do teachers need to overcome challenges of using AR in instruction?

Regarding the perceived challenges and needs to overcome them, we found three main categories. The first category concerns content - self-created and existing. For content creation, teachers complain about the lack of easy-to-use and cost-free authoring tools. For example, some teachers mentioned that they used the HP Reveal AR studio, which is now no longer available. Additionally, the teachers call for training on how to create AR objects, especially 3D models, and more time to prepare AR-enriched lessons. For existing AR materials, teachers report that these do not align with curriculum goals and lack of interactivity. Furthermore, the applications are not inclusive (e.g., usable on different devices) and not freely available. In sum, more high-quality AR educational materials are needed. The results in the content category are like those found in da Silva et al. (2018) and Alalwan et al. (2020), indicating that the problem of content is independent of the country. A detail stressed by the teachers in our study is that they request more materials in German.

Second, teachers experienced pedagogical issues during the AR classroom integration. These can be summarized as a lack of ideas for purposeful usage and perceived pitfalls that should be avoided. For example, teachers observed a so-called *wow-effect* that did not translate into more effective learning. To overcome this issue, training on how to purposefully use AR in class was suggested. This might also help to avoid the observed pitfalls like a distracting effect in terms of technical problems during the use. This issue is also reflected in the literature (Akçayır & Akçayır, 2017).

Third, technical issues like poor internet or the complete lack of devices that can easily display AR were also listed as problems by the teachers in our study. It is particularly interesting that one teacher pointed out that the use of students' smartphones can also cause problems. Some devices would simply no longer meet the requirements and have too little computing power for AR. The small display of smartphones was also mentioned as a limiting factor. Thus, teachers in the European, German-speaking context are struggling with the same technical shortcomings as the teachers in da Silva et al. (2018) and Alalwan et al. (2020).

Conclusion and implications

In summary, European (here: German-speaking) teachers face similar challenges when using AR as, for example, teachers in developing countries. To facilitate teachers' use of AR, different recommendations can be made.

School authorities, such as policy makers, need to provide a technical infrastructure so that the use of AR can take place smoothly and teachers can focus on instructional design considerations. Here, there is a need for trainings from teacher education institutes and continuing education providers that convey both the technical and pedagogical fundamentals for the use of AR in class. One concern of the teachers surveyed was that they would like to exchange ideas with others. Hence, it would be desirable to establish a networking platform that allows the exchange of AR materials, instructional designs, and experiences. It also became apparent that previous research has not yet been sufficiently successful in sustainably anchoring developed AR applications in practice. Future educational AR research should therefore integrate experimentally gained knowledge and technological approaches even more closely within practice. By directly involving teachers in these research and development processes, this can result in applicable, freely available, and reusable AR materials. Moreover, research can develop free and user-friendly AR design platforms to help harness the potential of teachers as a significant resource for content creation. Companies developing or willing to develop AR learning materials should also collaborate with both practitioners and researchers. As shown, the quality of many existing materials is considered poor. Collaboration among AR developers, educational technology researchers, and practitioners would certainly be able to contribute to more effective, efficient, and high-quality AR educational media in this regard.

To conclude, it was found that some teachers are in general willing to employ AR in the classroom for several reasons and with different instructional approaches, although these teachers still have to endure various challenges. To overcome these challenges, collaboration with research and other stakeholders is necessary to make AR an integral part of teachers' instructional toolbox.

References

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

Alalwan, N., Cheng, L., Al-Samarraie, H., Yousef, R., Ibrahim Alzahrani, A., & Sarsam, S. M. (2020). Challenges and prospects of virtual reality and augmented reality utilization among primary school teachers: A developing country perspective. *Studies in Educational Evaluation*, *66*, Article 100876. https://doi.org/10.1016/j.stueduc.2020.100876

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Computer Graphics and Applications*, *21*(6), 34–47. https://doi.org/10.1109/38.963459

Buchner, J., Buntins, K., & Kerres, M. (2022). The impact of augmented reality on cognitive load and performance: A systematic review. *Journal of Computer Assisted Learning*, *38*(1), 285-303. https://doi.org/10.1111/jcal.12617

da Silva, M. M. O., Radu, I., Schneider, B., Cavalcante, P., & Teichrieb, V. (2018). An Investigation on How Teachers are Using Augmented Reality in Their Lessons. *Anais do XXIX Simpósio Brasileiro de Informática na Educação (SBIE 2018)*, pp. 625–634. https://doi.org/10.5753/cbie.sbie.2018.625

Fominykh, M., Wild, F., Klamma, R., Billinghurst, M., Costiner, L. S., Karsakov, A., Mangina, E., Molka-Danielsen, J., Pollock, I., Preda, M., & Smolic, A. (2020). Model augmented reality curriculum. *Proceedings of the Working Group Reports on Innovation and Technology in Computer Science Education*, 131–149. https://doi.org/10.1145/3437800.3439205

Garzón, J., Kinshuk, Baldiris, S., Gutiérrez, J., & Pavón, J. (2020). How do pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and research synthesis. *Educational Research Review*, *31*, Article 100334. https://doi.org/10.1016/j.edurev.2020.100334

Ibáñez, M.-B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, *123*, 109–123. https://doi.org/10.1016/j.compedu.2018.05.002

Krüger, J. M., Buchholz, A., & Bodemer, D. (2019). Augmented reality in education: Three unique characteristics from a user's perspective. In M. Chang et al. (Eds,), *Proceedings of the 27th International Conference on Computers in Education* (pp. 412-422). Asia-Pacific Society of Computers in Education..

Kyza, E. A., & Georgiou, Y. (2019). Scaffolding augmented reality inquiry learning: The design and investigation of the TraceReaders location-based, augmented reality platform. *Interactive Learning Environments, 27*(2), 211–225. https://doi.org/10.1080/10494820.2018.1458039

Yoon, S. A., & Wang, J. (2014). Making the Invisible Visible in Science Museums Through Augmented Reality Devices. *TechTrends*, *58*(1), 49–55. https://doi.org/10.1007/s11528-013-0720-7