Challenges and Opportunities of Mixed Reality Systems in Education

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Abstract

Mixed reality gained much research attention in recent years due to the availability of capable hardware. Current smartphones allow people to immerse themselves in virtual worlds or explore digital artifacts through augmented reality applications. Schools, universities, and other educational establishment have started to equip students and pupils with tablets potentially capable of presenting mixed reality content. However, the development of compelling mixed reality applications that foster enhanced knowledge transfer lags behind. While the availability of mixed reality hardware offers new opportunities, it also creates challenges for content creators and educators. We discuss these challenges and opportunities and suggest directions for future research. We consider mixed reality as a chance to foster supportive and personalized learning experiences for everyone.

1 Introduction

Traditional teaching methods include the presentation of different disciplines in front of a number of students. Knowledge is transferred by a proficient person in this area, such as teachers or scholars. Since the overall education quality depends on the teacher-to-student ratio, information is diversely perceived by students. Larger classes require a generalization of content and increase the overall workload of teachers when it comes to individually support students (Kember and Gow, 1994). The understanding of novel topics for students can, therefore, be negatively affected (Gibbs and Jenkins, 2014).

To foster individual learning skills and alleviate the workload of supervisors, modern mixed reality (MR) systems have become an integral part for conveying knowledge within educational institutes (Kosch et al., 2017; Page, 2014). This includes the employment of Augmented Reality (AR) and Virtual Reality (VR) systems, which support students just-in-time with additional individualized content. Such systems do not depend on external instructors and can be used

Veröffentlicht durch die Gesellschaft für Informatik e. V. 2018 in
R. Dachselt, G. Weber (Hrsg.):
Mensch und Computer 2018 – Workshopband, 02.–05. September 2018, Dresden.
 https://doi.org/10.18420/muc2018-ws07-0471

at suitable times for students to learn new skills. Cognitive assistance is also provided, where visualizations are displayed in-situ to parallel occurring lecture sessions.

In contrast to information displayed on a screen, AR technologies offer new possibilities to engage directly with interactive digital content presented in a real environment (Azuma, 1997). VR, on the other hand, is an immersive experience of a simulated environment that allows altering the whole surrounding but is mostly cut off from the real world. Mixed reality, the continuous spectrum from virtual reality to augmented reality, is again actively researched.

With the proliferation of smartphones, smartwatches and tablets into the general population, access to educational content became omnipresent. For example Billinghurst (Billinghurst, 2002; Billinghurst and Duenser, 2012) surveyed and demonstrated the use of low-cost technology to provide immersive mixed reality experiences during different learning scenarios. However, presented information remains static and often does not offer user interaction, making it not much different from a regular textbook. While the vision of ubiquitous computing is still an active research challenge (Weiser, 1999), current state-of-the-art teaching modalities do not blend educational information with their environment.

With enhanced hardware and software solutions available, mixed reality applications have been explored beyond the lab by various researchers. For example, recent research has shown that using AR glasses to visualize the current state of an experiment in physics class and foster a greater understanding of the teaching material (M. P. Strzys et al., 2018). However, a comprehensive analysis of 87 mixed reality learning applications, including an in-depth analysis of seven applications, reveals that mixed reality applications have diverse effects on the students' performance (Santos et al., 2014). The impact of deploying mixed reality applications in educational settings should be discussed critically since the design of mixed reality applications in education opens new design spaces.

Previous work has shown that mixed reality apps are on the rise due to cheaper hardware and low prototyping costs. However, the impact of mixed reality applications needs to be investigated with precaution since long-term effects are unknown. In our work, we (a) highlight the need to tackle the open questions on how meaningful mixed reality applications can foster knowledge sharing among students and (b) discuss the opportunities for new learning and teaching methods through novel technologies.

2 Challenges

While there is potential to use MR for improved learning experiences, it also can overload the learner with too much information at the same time. Redundant or obtrusive representations may overwhelm or annoy the user. Therefore, the development cycle of learning applications should include an awareness of visual overloads and an intelligent placement of information.

2.1 Pedagogical Challenges

The use of MR in educational settings changes past pedagogical techniques (Glover and Miller, 2001). The acceptance of the teacher and student regarding the used technology is a given requisiteness. Two factors emerge when it comes to using assistive technologies. The first factor comprises the usage of technology to improve the overall teaching efficiency. The second factor includes the teacher attitude towards technologies. When both factors come together, the probability of using MR applications successfully increases. This requires teachers to be prepared towards such technologies.

The representation of information for both teacher and student plays a crucial role in conveying knowledge. Learning activities should include well designed interactions with the peers as well as with the system (Hughes et al., 2005). The rendering of supporting virtual visualizations should be kept at a minimum to avoid information overload. Elements should be placed in the field of view of the user if it can blend with the environment. Otherwise, visualizations are perceived as obtrusive. Finally, the incorporation of physical activities has shown a positive effect on learning experiences (Lindgren and Johnson-Glenberg, 2013).

2.2 Technical Challenges

Hardware has developed rapidly and the first completely self-contained wearable MR devices became affordable for researchers and end-users. Still, most devices are in its infancy stage. This includes a limited battery life, a small field of view, and an uncomfortable feeling when being worn for several hours. Due to the fast technical advances, these challenges will most likely be solved in the upcoming years.

Since technical boundaries will be overcome in the future, the research question of how to develop meaningful MR environments for learning still remains. This includes the interaction in augmented and virtual realities. Currently, most MR devices support interaction via physical remotes, hand gestures, or speech. However, to enable collaborations with peers and virtual elements, implicit hands-free interaction should be supported. Speech allows this kind of hands-free interaction but is most likely to be unsuited for classroom use due to background noise and social acceptance. Mid-air hand gestures are unsuited as an input modality since they cause fatigue (Boring et al., 2009) when used repeatedly. It still is an open research question of how to design an expressive interaction concept for MR learning experiences.

3 Opportunities and Future Research Directions

In the following, we will highlight four opportunities where we envision that education can benefit from the usage of mixed reality applications. In particular, we think of the great potential of mixed reality environments when deployed in universities to support the comprehension of complex scenarios in applied science and lab courses.

3.1 Improve Learning though Amplification

When making efforts to improve learning ability, human memory, and recall research proposes to spread out the learning process and information presentation (Dingler et al., 2016). Recent findings of a lab study using MR glasses indicate that complex experiments could benefit from augmentation M. Strzys et al., 2018. This motivates to enrich further learning material to foster a better understanding of complex relationships. It is promising to apply these new technologies within practical lab courses. We suggest developing MR applications that enable learners to actually see and understand the fundamental facts. Specialized sensors can measure environmental data or the current status of an experiment. Voltage and current could be directly displayed within the wires during electrical engineering classes (Beheshti et al., 2017) or heat propagation in metals within physic classes (M. P. Strzys et al., 2018). MR displays in combination with sensors allows us to extend the human vision and visualize in-depth details of learning material in place of occurrence.

3.2 Personalized Learning

According to the National Educational Technology Plan (Thomas, 2016) personalized learning allows each learner to learn at an optimized personal pace with an instructional approach tailored for the needs of each learner. Current interactive learning applications follow this idea and optimize learning material to be meaningful and relevant to the learner. In MR learning experience, this concept can be adapted and even developed further. While consuming difficult material or conducting advanced experiments, learners could receive adjusted and immediate feedback through AR overlays. While learning or running MR supported experiments the system can video record the environment, experiment, and virtual overlay. Difficult learning material can later be revisited or even be played back in VR. Further, learners could create personal notebooks of AR experiences recordings on the fly.

3.3 Extension

Many educational establishments are limited regarding their financial resources. These have a direct impact on the quality of teaching and education. Once deployed, MR systems can overcome this limitation and enhance learning. In addition, interactive learning and exploring environments can be created that extend the current body of learning material. We envision interactive experiments that were not possible to realize before because of time, financial, or security constraints. For example, chemistry students could safely explore chemical reactions with hazardous elements or biology students can examine samples under an augmented microscope that are usually not accessible.

3.4 Ubiquitous Learning

Learning can be considered as an ongoing, voluntary, and self-motivated pursuit of knowledge (Cliath et al., 2000). MR systems can support continuous learning by presenting chunks of knowledge spatially and temporally distributed. Research showed that ubiquitous learning can be more effective and engaging (Ibrahim et al., 2017). While this may apply for language learning, it is an open research question of how ubiquitous MR learning systems should be integrated into everyday life.

We envision that MR learning experiences can create more meaningful and relevant learning scenarios that potentially lead to greater engagement and learning success. We encourage an open discussion and further development and research to understand how to create significant MR learning systems.

4 Conclusion

Traditional teaching methods are undergoing a change from paper-based learning material to more interactive and computer supported solutions. After making knowledge widely accessible through web-based collaborative encyclopedias, online video lectures and massive open online courses the next step is to make even complex learning material understandable. Mixed Realities (MR) enable us to create compelling learning environments and explain even complex scenarios when well thought through. We expect, that MR environments will be available in the near future for a broader audience. In this paper, we discussed how MR systems open new challenges and chances in the education sector. In particular, we discuss pedagogical and technical challenges as well as the wide options of personalized, improved, and ubiquitous learning. For the future, we envision the availability of MR systems in the education system to support personalized and engaging learning materials for a variety of use cases.

5 Acknowledgements

This work was supported by the German Federal Ministry of Education and Research as part of the project Be-greifen (Grant No. 16SV7527) and KoBeLU (Grant No. 16SV7599K). This work was partly conducted within the Amplify project funded from the European Research Council (ERC) (grant agreement no. 683008).

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