DOI: https://doi.org/10.56198/ZH3JOHYEA

Work-in-Progress—Preservice Teachers' Perceptions of Advantages of Virtual and Augmented Reality Technology in the Everyday K-12 Classroom

David Fernes[1], Andreas Dengel[1], Jonas Maurer[1] and Hai Hoang Pham[1]

[1] Goethe University Frankfurt, Frankfurt, Germany
fernes@em.uni-frankfurt.de

Abstract. As immersive technologies enter school classrooms, teachers begin to adopt these technologies for their respective subjects. But the potentials and advantages differ between subjects and technologies, which is why it is interesting to investigate how future teachers perceive these advantages. Following the learning affordances from Dalgarno and Lee, the SAMR model of Puentedura, and the visualization forms of representation from Schwan and Buder, we analyzed fictional letters from preservice teachers attending a seminar on immersive teaching and learning according to these categories. This work-in-progress paper presents the results on the following research questions: 1) How do reported a) learning affordances, b) technology integrations, and c) visualization forms differ between virtual reality and augmented reality? and 2) How do reported a) learning affordances, b) technology integrations, and c) visualization forms differ between subjects? Results indicate that VR and AR offer different sets of advantages for learning. Based on these results guidelines for which technology to use under which circumstances can be derived. While there also may be differences between subjects this preliminary study could not offer clear insights in this regard.

Keywords: Immersive Education, Teacher Training, Virtual Reality, Augmented Reality.

1 Introduction

With virtual reality headsets getting cheaper and better and more educational content being available for both virtual and augmented reality these technologies play an ever-bigger role in education. It has been shown that these technologies are able to improve learning outcomes [16] by offering many different benefits for teaching like helping to remember spatial information [12] or increasing motivation [4]. There are also many different use cases for using these technologies for teaching and learning for a variety of subjects [10], like computer science [9] or history [1].

Which of these benefits and use cases are important may vary depending on what technology is used and which subject is taught. To better understand which benefits are important in which situation investigating the opinions of teachers is important. They know best what kind of content they want to use in their classroom for their subjects. Since not all teachers might know how to effectively use VR and AR in the classroom teachers that already have experience with these technologies should be asked.

In order to investigate teachers' opinions, we analyzed fictional letters about the benefits and use cases of virtual and augmented reality written by preservice teachers as part of a university course about teaching with immersive media. We focused this analysis on Dalgarno and Lees learning affordances [4], Puenteduras levels of technology integration [18] and Schwan and Buders visualization forms [19] in order to answer the following research questions:

- **Research Question 1:**

a) How do reported learning benefits differ between virtual reality and augmented reality?
b) How do reported classroom integrations differ between virtual reality and augmented reality?
c) How do reported visualization forms differ between virtual reality and augmented reality?

- **Research Question 2:**
  a) How do reported learning benefits differ between subjects?
  b) How do reported classroom integrations differ between subjects?
  c) How do reported visualization forms differ between subjects?

2 Theoretical Background

The literature on immersive learning reports various benefits for VR and AR: Through the intimate relationship between virtual and physical objects in AR, physical objects can be enhanced in ways that are not normally possible. As potential uses, Billinghurst names dynamic information overlays, private and public data display, context sensitive visual appearance, and physically based interactions [2]. Based on these potentials, Yuen, Yaoyuneyong, and Johnson promote five educational directions for AR: AR books, AR gaming, discovery-based learning, object modeling, and skills training [20].

For VR, Kavanagh et al. summarize motivations for using this technology in education: Most learning applications are based on either constructivism, collaboration, or gamification. As intrinsic factors enhancing learning, increased immersion, motivation, and enjoyment as well as personalized learning contents and deeper learning are reported [13]. Dengel and Mägdefrau argue that for all immersive technologies and subjects, the perception of non-mediation might be a strong predictor of learning outcomes [8]. In a different framework Makransky and Petersen also describe a variety of factors influencing learning outcomes of immersive VR applications. These factors include interest, motivation, self-efficacy, embodiment, cognitive load, and self-regulation [14].

While some factors are similar between AR and VR, there are notable differences in how the potentials are emphasized in the literature.

In an extensive literature review, Freina and Ott report different applications of VR in various educational subjects, such as Computer Science, Engineering, Social Sciences, Medicine, Mathematics, Decision Science, Material Science, Physics, and more [10]. Literature reviews focusing on individual subjects' present potentials such as the use of mindful abstractions and metaphorical representations, kinesthetic learning, and visual features to assist interactions in STEM Education [17].

For language learning, immersive learning could increase motivation, activate visual and motor channels to understand the learning content within the context, also, immersive experiences could foster enjoyment and fun with AR and VR tools. Also, creating interaction could help develop in-depth language skills [11].

Challenor and Ma analyzed applications for history education and found that AR can help creating higher learning retention, emotional understanding and empathy. Especially the virtual representation of destroyed historical sites can give accurate depictions of the past based on the historical evidence [3].

Similar to the comparison of AR and VR, the potentials of immersive technologies for the different subjects seem to share some common ground but differ in their respective applications. These differences frame the research of this article: The implementation of immersive learning in the everyday classroom strongly relies on the perceptions of the teachers about the underlying technologies [6], which is why we wanted to investigate how preservice teachers perceive these advantages of AR and VR related to their respective school subjects.

For this study three frameworks for categorizing learning benefits, use cases and visualizations for VR and AR were used.

Dalgarno and Lee [4] defined several benefits for learning with immersive technology which they call "learning affordances for virtual reality". These five affordances are as follows:

- **A1:** facilitation of tasks that lead to enhanced spatial knowledge representation.
- **A2:** greater opportunities for experiential learning
- **A3:** increased motivation/engagement
- **A4:** improved contextualisation of learning
- **A5:** richer/more effective collaborative learning

The SAMR model by Puentedura [18] defines different levels of technology use for education, depending on how much a learning task is changed when adapting it to the technology. The four levels are as follow:

- **Substitution:** The learning task is adapted to the technology without change.
- **Augmentation:** Some improvements are made to the task through technology

- **Modification:** The task is significantly redesigned through the use of technology
- **Redefinition:** Completely new tasks are created that would not be possible without technology.

Schwan and Buder [19] defined different forms of visualization for immersive learning content. Which form should be used depends highly on the learning content. These visualization forms are:

- **V1:** Faithful visualizations try to recreate reality as closely as possible.
- **V2:** Schematic visualization adds some abstraction or simplification to the representation.
- **V3:** Concretizing visualization is used for abstract topics that can normally not be visualized.
- **V4:** Metaphoric visualization uses analogies to represent difficult to understand topics.

It can be assumed that all three of these factors depend on which technology is used and which subject is taught. Therefore, our hypotheses are as follows:

- **Hypothesis 1:**
  a) Reported learning affordances differ between virtual reality and augmented reality.
  b) Reported technology integrations differ between virtual reality and augmented reality.
  c) Reported visualization forms differ between virtual reality and augmented reality.
- **Hypothesis 2:**
  a) Reported learning affordances differ between subjects.
  b) Reported technology integrations differ between subjects.
  c) Reported visualization forms differ between subjects.

3 Method

3.1 Sample

The participants for this study where 13 German preservice teachers from two different German universities. All participants were currently taking part in a university course about teaching with virtual and augmented reality [7]. This could guarantee that they had at least a basic understanding of the possibilities of immersive media for education, which may have not been the case for most teachers. 7 participants identified as female, 4 as male. 3 participants did not mention their gender or age. The mean age of participants that mentioned their age was 21.3 (SD=1.2).

For this study, the results of a homework exercise for the students were analyzed. While the homework was mandatory for course participants, participation in the study was voluntary, meaning that only the work of those 13 students that agreed to take part was evaluated.

Each student answered the homework question for exactly one of their future subjects. The subjects mathematics, sports and languages were chosen by two students each. The subjects history, chemistry, arts, computer science, economics and religion were chosen by only one student each.

One participant completed only the half of the task focused on virtual reality and not the second part focusing on augmented reality. This participant was excluded for the comparison between technologies since it would skew the comparison in favor of VR. This participants' responses were still evaluated for the comparison between subjects.

3.2 Instruments

The evaluated homework task was as follows (translated from German):

"Your (fictional) school still has funding available for your subject area in this budget year. After attending the great seminar "Immersive Media in the Classroom", you decide that purchasing a class set of virtual reality and augmented reality glasses might be a useful purchase for improving your subject teaching. Write a short, one-page letter to your fictional director, stating, specifically related to your subject (choose one of your subjects):

- 3 advantages of virtual reality for teaching (include 3 specific examples).
- 3 advantages of Augmented Reality for teaching (include 3 specific examples)"

This homework task was given after the students learned about general concepts of virtual reality but before the potentials and benefits of the technology for learning were discussed. This was done so that the participants would not be biased by the course contents. The format for the homework was chosen to be as open as possible so that the participants would also not be biased by the question.

3.3 Procedure

Students had two weeks to write and submit their letters for the homework. The assignment was voluntary, and the documents were anonymized after submission. The letters were then analyzed by two raters using qualitative content analysis [15] with MAXQDA. During the first iteration, we observed a low interrater reliability for the reported benefits ($\alpha = .28$), visualization forms ($\alpha = .45$), and the SAMR task descriptions ($\alpha = .30$), which is why a third rater was added for a final rating to resolve the differences.

4 Results

For the comparison of technologies, it was counted by how many different students each learning affordance, visualization form and SAMR level was mentioned in the VR and the AR part of the letter. The number of mentions was then compared between the technologies.

The affordance "Facilitation of tasks that lead to enhanced spatial knowledge representation" was mentioned by 4 participants as a benefit of AR and by 6 as a benefit of VR. "Greater opportunities for experiential learning" were mentioned by 6 people for AR and by 7 for VR. "Increased motivation/engagement" was mentioned by 5 participants for AR and by 6 for VR. "Improved contextualization of learning" was listed as a benefit by 4 people for AR and by 9 for VR. "Richer/more effective collaborative learning" was mentioned by 3 participants each for both technologies as an affordance (see Fig. 1).

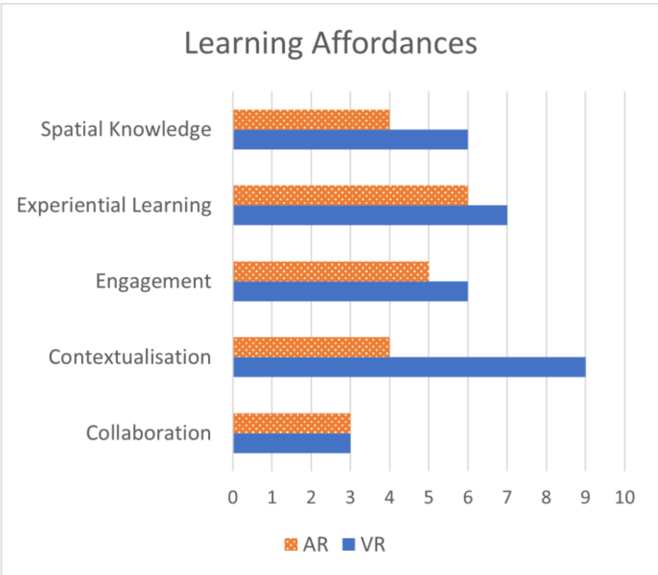

Fig. 1. Number of students who mentioned each learning affordance for VR and AR.

The SAMR level substitution was mentioned by 4 participants for AR and by 6 for VR. The augmentation level was listed by 7 people for AR and by 9 for VR. Modification was mentioned by 5 for AR and 3 for VR. The redefinition level was mentioned by 3 participants for AR and by 6 for VR (see Fig. 2).

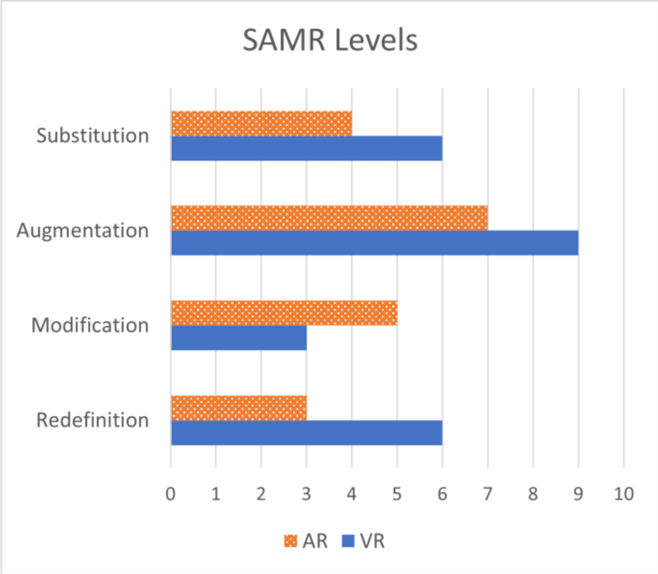

Fig. 2. Number of students who mentioned each SAMR level for VR and AR.

Faithful visualization was mentioned by only 1 participant for AR and VR each. 9 people mentioned schematic visualization for AR and 5 mentioned it for VR. Concretizing visualization was listed 3 times for AR and 2 times for VR. Metaphoric visualization was mentioned 3 times for both AR and VR (see Fig. 3).

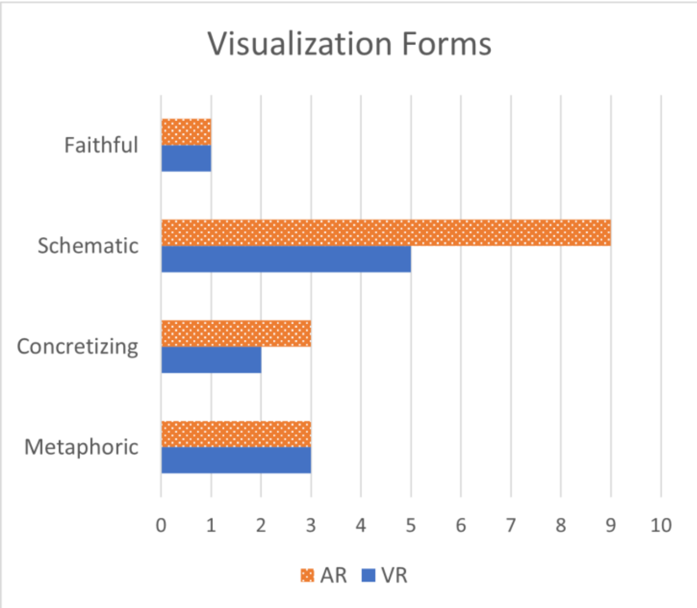

Fig. 3. Number of students who mentioned each visualization form for VR and AR.

Since most subjects had only one participant for the comparison between subjects counting the number of mentions would not be very useful. Instead, only if a given point was mentioned at least once was compared. Each learning affordance was mentioned at least once for the subjects sports and languages. For computer science none of the affordances were mentioned. For all other subjects only some affordances were mentioned. For the subjects history, mathematics, sports and languages, each SAMR level was mentioned at least once. For all other subjects at least some SAMR levels were mentioned. For the subject religion each visualization form was mentioned at least once. For computer science none of the forms were mentioned. For all other subjects only some forms were mentioned.

5 Discussion and Limitations

The results seem to indicate that preservice teachers see different affordances as important dependent on the technology. When looking at VR applications "improved contextualisation of learning" is mentioned by most participants as a benefit of the technology, while the affordances are more evenly ranked for AR. Nonetheless each affordance is listed by more people for VR than for AR except for "richer/more effective collaborative learning" which was mentioned the same number of times for both technologies. This would indicate that in order to leverage improved contextualisation using VR makes the most sense while both technologies can be used when another affordance is important.

When looking at which SAMR levels were mentioned as examples for both technologies the results seem to be more similar between AR and VR. For both technologies Augmentation is the most common level with VR still having 2 more mentions than AR. For the other levels VR seems to be more often applied to substitution and redefinition while AR is preferred for Modification. This indicates that when using VR, it makes more sense to substitute, augment or redefine tasks and when using AR modification seems to be a better choice.

A schematic visualization seems to be the most preferred for both technologies, but it is even more prominently mentioned for AR examples. All other visualization forms are mentioned less than schematic visualization and a comparable amount of time for both technologies. This indicates that schematic visualization is the preferred form of visualization for both AR and VR but augmented reality is preferred by teachers.

These results seem to indicate that H1 a) and b) can be assumed true. For H1 c) the results are less clear since while schematic visualization is mentioned by more people for AR the ranking of the four forms is still the same for both technologies.

It is harder to make any assumptions about how benefits and use cases compare between subjects. The reason for this is the low number of participants in general with participants being spread over a large number of different subjects. This makes it difficult to make assumptions about differences between subjects since most subjects had only one participant. Because of these limitations it is still unclear whether H2 can be assumed true or false. It would be of interest to replicate this study with more participants in the future to get clearer results on RQ2, since differences in the use cases and benefits of these technologies between subjects would still be interesting to investigate.

One other problem with the evaluation of the learning affordances may also be that the original concept of the course was mainly focused on VR, which might explain why the majority of reported affordances and task descriptions is related to VR. As the students were expected to design their own educational immersive VR experience for their respective subjects, they are likely to have thought more about the potentials of VR in general. Another limitation of this study is that we only focused on the potential benefits while (for the time being) ignoring the challenges arising when using immersive technologies. A study especially focusing on the challenges of immersive media in the classroom is planned to be carried out with experienced teachers (as they might have a better understanding of the daily general conditions in schools). Experienced teachers may also have different perspectives on the advantages and benefits of these technologies making a replication of this study with teachers interesting.

6 Implications for Classroom Integration of Immersive Media

Results show that according to preservice teachers whether VR or AR technologies should be used in a specific learning context can depend on what kind of task is implemented and how the information should be visualized. Both technologies are also able to make use of different benefits of immersive learning to different degrees.

This should be taken into account when developing learning applications with these technologies in order to use their full potential. Teachers should also consider these differences when choosing technologies and applications for use in their classroom. From our results there are some implications for how to use AR and VR as well as which technology to choose in a specific contexts can be deduced.

When using AR:

- "greater opportunities for experiential learning" is the most important benefit.
- "richer/more effective collaborative learning" is less important than other benefits.
- tasks should be either be augmented or modified through the technology.
- a schematic visualization should be used.
- a faithful visualization is less useful.

When using VR:

- "improved contextualisation of learning" is the most important benefit.
- "richer/more effective collaborative learning" is less important than other benefits.

- tasks should preferably be augmented through the technology.
- while augmentation is preferred substitution or redefinition can also be used.
- a schematic visualization should be used.
- a faithful visualization is less useful.

When deciding between AR and VR:

- VR should be chosen when "improved contextualisation of learning" is important.
- VR should be chosen when using substitution augmentation or redefinition of a task.
- AR should be chosen instead when modification of a task is used.
- AR should be chosen when using a schematic visualization.
- both technologies are largely comparable in most other circumstances.

While it can be expected that the reported benefits and use cases also vary between different subjects this study was not able to confirm or further specify those. Since there were only a few participants per subject this study should be replicated with a larger sample size, which also includes more experienced teachers, in order to investigate these differences further in the future.

References

1. Bekele, M.K., Pierdicca, R., Frontoni, E., Malinverni, E.S., Gain, J.: A survey of augmented, virtual, and mixed reality for cultural heritage. Journal on Computing and Cultural Heritage (JOCCH) 11(2), 1–36 (2018).
2. Billinghurst, M.: Augmented reality in education. New horizons for learning 12(5), 1–5 (2002).
3. Challenor, J., Ma, M.: A review of augmented reality applications for history education and heritage visualisation. Multimodal Technologies and Interaction 3(2), 39 (2019).
4. Dalgarno, B., Lee, M.J.: What are the learning affordances of 3-d virtual environments? British journal of educational technology 41(1), 10–32 (2010).
5. Dede, C.J., Jacobson, J., Richards, J.: Introduction: Virtual, augmented, and mixed realities in education. In: Virtual, augmented, and mixed realities in education, pp. 1–16. Springer (2017).
6. Dengel, A., Buchner, J., Mulders, M., Pirker, J.: Levels of immersive teaching and learning: Influences of challenges in the everyday classroom. In: Immersive education: Designing for learning, pp. 107–122. Springer (2023).
7. Dengel, A., Fernes, D.: A course curriculum for immersive teaching and learning in initial teacher education. In: Society for Information Technology & Teacher Education International Conference. pp. 1020–1027. Association for the Advancement of Computing in Education (AACE) (2022).
8. Dengel, A., Mägdefrau, J.: Immersive learning explored: Subjective and objective factors influencing learning outcomes in immersive educational virtual environments. In: 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE). pp. 608–615. IEEE (2018).
9. Dengel, A., Mägdefrau, J.: Immersive learning predicted: Presence, prior knowledge, and school performance influence learning outcomes in immersive educational virtual environments. In: 2020 6th International Conference of the Immersive Learning Research Network (iLRN). pp. 163–170. IEEE (2020).
10. Freina, L., Ott, M.: A literature review on immersive virtual reality in education: state of the art and perspectives. In: The international scientific conference elearning and software for education. vol. 1, pp. 10–1007 (2015).
11. Huang, X., Zou, D., Cheng, G., Xie, H.: A systematic review of ar and vr enhanced language learning. Sustainability 13(9), 4639 (2021).
12. Jensen, L., Konradsen, F.: A review of the use of virtual reality head-mounted displays in education and training. Education and Information Technologies 23(4), 1515–1529 (2018).
13. Kavanagh, S., Luxton-Reilly, A., Wuensche, B., Plimmer, B.: A systematic review of virtual reality in education. Themes in Science and Technology Education 10(2), 85–119 (2017).
14. Makransky, G., Petersen, G.B.: The cognitive affective model of immersive learning (camil): A theoretical research-based model of learning in immersive virtual reality. Educational Psychology Review 33(3), 937–958 (2021).
15. Mayring, P., et al.: Qualitative content analysis. A companion to qualitative research 1(2), 159–176 (2004).
16. Merchant, Z., Goetz, E.T., Cifuentes, L., Keeney-Kennicutt, W., Davis, T.J.: Effectiveness of virtual reality-based instruction on students' learning outcomes in k-12 and higher education: A meta-analysis. Computers & Education 70, 29–40 (2014).
17. Pellas, N., Dengel, A., Christopoulos, A.: A scoping review of immersive virtual reality in stem education. IEEE Transactions on Learning Technologies 13(4), 748–761 (2020).
18. Puentedura, R.: Transformation, technology, and education (2006).
19. Schwan, S., Buder, J.: Virtuelle realität und e-learning. E-Teaching. org, Tübingen (2006).
20. Yuen, S.C.Y., Yaoyuneyong, G., Johnson, E.: Augmented reality: An overview and five directions for ar in education. Journal of Educational Technology Development and Exchange (JETDE) 4(1), 11 (2011).