AUGMENTED REALITY IN PRIMARY EDUCATION: TEACHERS' PERSPECTIVES ON POTENTIAL AND BARRIERS

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Abstract

Research findings suggest that Augmented Reality (AR) can be a beneficial tool for teaching and learning practices but brings about certain challenges at the same time. Teachers are central stakeholders in the educational use of AR; given their daily classroom practice, they are also experts in the evaluation of the advantages and disadvantages of respective innovative educational technologies. Yet, few studies systematically analysed teachers' opinions and experiences about the advantages and problems in the educational use of AR technologies so far. In response to this desideratum, the following paper presents results from a systematic and category-based qualitative content analysis based on an interview study. The input was collected from a heterogeneous and international convenience sample of n=11 teachers after they had piloted one out of three AR-enhanced learning apps in their daily classroom practice. The results confirm that increased student motivation and classroom engagement and advanced learning achievements are considered the predominant advantages and that issues with software and technology were perceived as the biggest problems in the pilot study. Furthermore, dimensions of motivation and classroom engagement are considered in detail to achieve an in-depth analysis and to bring forward important recommendations for further developments and for teachers' future educational use of AR technologies.

Keywords: Augmented Reality, technology-enhanced teaching and learning, teachers' perspectives, primary education, international comparative research.

1 INTRODUCTION: THE IMPORTANCE OF TEACHERS' PERSPECTIVES ON THE EDUCATIONAL USE OF AR

According to recent research, Augmented Reality (AR) offers multiple benefits for teaching and learning processes, such as increased student motivation, a better understanding and higher retention of knowledge, or increased collaboration among students [1]. At the same time, common barriers to the integration of AR into classroom practice are evident, such as an inefficient integration into classroom processes, resources, or issues with software and devices [1].

Ultimately, teachers are key stakeholders in the network of factors that influence if and how digital media in general and innovative Mixed Reality technologies in particular are integrated into classroom practices. As initiators and facilitators of teaching and learning processes, they are responsible for the thorough integration of innovative approaches into pedagogical practices. Their knowledge and experiences also qualify them as valuable experts in the evaluation of the advantages and disadvantages of methods and tools [2]. While a number of related studies already focus on the teachers' perspectives about the integration of AR into classroom practices, these studies are often limited in their focus, in the scope of nationalities included and in their methodological rigour [2].

Against this background, the present study explores the perspectives of primary school teachers from diverse educational settings and countries about their experiences with the integration of AR into their teaching. Data were collected in the context of an international interview study following the inclusion of one out of three AR-enhanced learning apps in classroom practice. In this context, the following two research questions are addressed:

Which *advantages* of the educational use of AR-enhanced learning apps do international primary school teachers describe after piloting an AR-enhanced learning app in their lessons?

Which *problems and barriers* to the educational use of AR-enhanced learning apps do international primary school teachers identify after piloting an AR-enhanced learning app in their lessons?

2 STATE OF RESEARCH

While AR has been widely studied in terms of learning effectiveness [3], [4], studies that focus specifically on teachers' subjective assessments of the benefits and disadvantages of AR in the classroom, as well as related experiences and attitudes, are less common [5]. While exploring the field of research, quantitative survey studies can first be distinguished with regard to the teacher perspectives collected on the basis of the Technology Acceptance Model (TAM) by Davis [6]-[10]. Findings indicate a strong positive correlation between teachers' perceived ease of use, attitudes towards the use of AR and its perceived usefulness for teaching and learning [7]. Across several studies, the acceptance of teachers towards AR was identified to be high [8]-[10].

While teachers were generally described to be familiar with AR in some studies [8]-[10], other sources came to the conclusion that a majority of teachers are unfamiliar with AR as such [5], [11]. Consequently, several studies describe that most teachers lack experience with the educational uses of AR [2], [8], [11]. It appears that teachers in many countries are still in an exploratory phase when using AR in the classroom [12].

Teachers' attitudes and willingness to cooperate were identified as important supportive factors for the integration of AR into teaching and learning [11]. Teachers who had used AR in the classroom reported that they were satisfied, found integration easy, and had the intention to continue using AR [11].

As central benefits of the educational use of AR, respondents in the studies identified

- Increased student engagement [13], [14],
- Increased student motivation [11], [14], and
- Enhanced possibilities for students' learning [11], e.g., through better spatial visualization [5] as well as active learning [5] and independent learning [11].

On the other hand, poor infrastructure at schools, lack of authoring tools, lack of time, and also insufficient pedagogical knowledge was described as the biggest obstacles to using AR effectively [12]. Similar topics and findings prevail in further related studies [2], [5], [11], [15]; among the most frequently mentioned perceived barriers towards the educational use of AR, the following aspects were reported:

- Time constraints/requirements [2], [1],
- Lack of financial resources [11], [15],
- Students' lack of ICT skills [2], and
- Lack of knowledge and training on the part of teachers [11].

[16] compared the perceptions of teachers who had tested an AR application during a two-hour workshop with those of colleagues who had tried a VR application. Results show that AR was rated slightly higher in terms of its potential for collaborative learning by teachers using AR as compared to teachers using VR. Furthermore, AR was perceived as easier to use and had fewer obstacles to adoption than VR. Findings from the evaluation of a 3-month professional development on AR in the classroom by [17] showed that teachers' experience with AR in educational contexts increased, as did the number and sophistication of perspectives, e.g. related to motivation-related benefits or barriers regarding the availability of appropriate hardware and connectivity issues.

From a contextual viewpoint, there are a few relevant studies which investigate the experiences and perceptions of pre-service teachers based on longer periods of teaching with AR [14], on engagement with AR during professional development sessions [13],[16],[17], or on systematic educational design activities using AR applications [18]-[20]. At the same time, many studies focus on participants from one country or university context only. As a conclusion from reviewing the state of research, there is a desideratum for a systematic analysis of qualified international teachers' perspectives on AR in teaching and learning settings.

3 RESEARCH METHODOLOGY

3.1 Project context and research design

Against the background of the research desiderata identified, data were collected in the context of the European ARETE project which focuses on AR in primary education. One objective of this project is to develop and pilot AR-enhanced learning apps for literacy learning, mathematics and science in more than 100 primary schools across Europe and to systematically evaluate, among other factors, the usefulness, usability and pedagogical value of AR technologies in primary educational settings [21], [22].

For this purpose, a complex interdisciplinary research design was developed. The qualitative interview data presented in the following were collected in two pilot studies in one focus group and two single interviews conducted after the intervention, i.e., after the teachers had worked with their app (either on mathematics, science or literacy learning) in their classes. The timeframe for working with the apps ranged from a few weeks to a whole school term, depending on the app and the individual piloting circumstances. The aim of this research was to systematically identify teachers' perspectives on the potential and barriers of AR in primary education.

The research approach for ARETE pilots 1 and 2 is presented in Fig. 1:

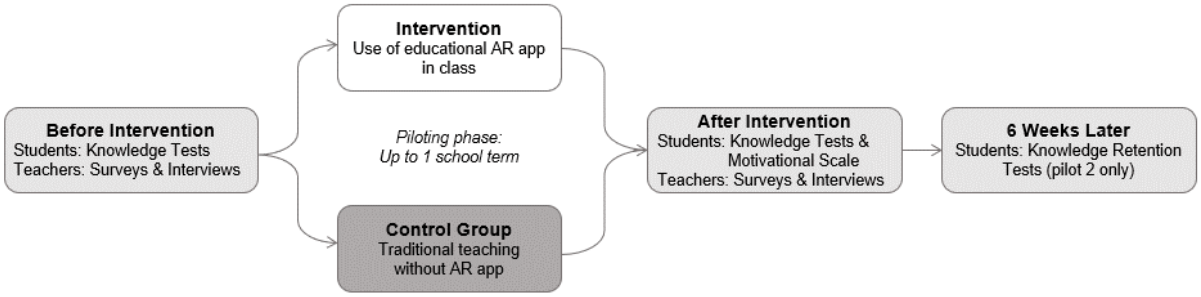

Figure 1. ARETE Pilot 1 and 2 Research Approach.

The interview questioning routes applied for the teacher interviews pre and post-intervention were developed following [23] and [24]. The interviews conducted after the intervention, which are analyzed in the following, included the following elements:

- An opening question to introduce participants,
- An introductory question about previous experiences with AR in teaching and learning settings,
- Key questions about the implementation, focussing on the integration of AR into lessons, things that went well, difficulties during the implementation, and effects of the app use on students,
- A key question about future perspectives on AR use, and
- An ending question with a rating of the overall success of the pilot.

The interviews were conducted online, recorded, transcribed and analysed by a qualitative content analysis [25] using the MAXQDA software. Two qualified researchers coded the material independently. The ratings were then compared one by one and a final version was agreed upon.

In the analysis, the teachers' statements were classified using a coding system which was developed deductively based on relevant literature and amended inductively based on the responses. Against the background of the results from the literature review, a focus in the context of the advantages of AR was put on the analysis of motivation, classroom engagement and learning achievements [26], [27]. Problems and barriers were analysed according to the inductively developed main categories of app and technology, teachers and students, and the piloting context.

3.2 Study sample

For the ARETE project, a convenience sample of teachers was recruited in open calls and via the Scientix network (http://www.scientix.eu/). While approximately 100 teachers were involved in the testing and piloting of the three different apps, 11 volunteering teachers were engaged as teacher

coordinators. They were responsible for the coordination of piloting activities and communication with pilot teachers in their respective countries while also participating in the AR-enhanced teaching activities themselves. Hence, they were qualified for the interviews to reflect upon their own experiences and to summarize the piloting experiences the teachers in their countries reported.

ARETE pilot 1 was about literacy learning for primary students with reading and spelling difficulties [22]. Two teacher coordinators (1 female, 1 male) from Ireland were in charge of the teachers in this pilot study. Overall, there were 8 teachers coming from three countries (Ireland, Italy and Luxembourg) who completed this pilot. As one teacher coordinator was replaced by another person during the phase of pre interviews, the two teacher coordinators were surveyed in two separate online single interviews with a duration of approximately one hour each.

ARETE pilot 2 focussed on mathematics and science learning in primary school using two relevant AR-enhanced apps [21]. A group of n=9 teacher coordinators (5 females, 4 males) was responsible for attending to the 91 pilot teachers in this pilot study. The 9 teacher coordinators who participated in the focus group of approx. 1:30 hour duration came from the following countries: Greece, Croatia, Serbia, Spain, Portugal, Turkey, Italy, Romania and Poland.

Overall, the 11 teacher coordinators interviewed were a heterogeneous group of teachers from diverse backgrounds including private and public schools, single-sex and coeducational schools, from rural and urban areas. As an analysis of interview responses regarding these teachers' technology acceptance and previous experience with AR revealed, all of them demonstrated a generally open and positive attitude towards technology-enhanced teaching and learning; some teacher coordinators also mentioned previous practical experience with the use of AR in teaching and learning contexts.

4 RESULTS

In the interviews, the teachers mentioned a number of advantages they discovered when using AR in their lessons; they also talked about several problems and barriers they encountered. In the following, the respective results of the qualitative content analysis will be summarized. The codes following the quotes mark the pilot (P1 or P2) and the teacher coordinator with his or her gender (male = M, female = F) and a randomly assigned number.

4.1 Findings on advantages of the educational use of AR

Based on relevant findings from related literature as introduced above, it was expected that teachers would mention enhanced motivation and classroom engagement as well as knowledge gain/ effective learning as the most significant advantages.

To systematically assess the impact of the AR-based intervention on student motivation, Keller's well-established ARCS model was used as a reference [26]. According to this model, student motivation can be stimulated by an AR app addressing students' feelings of attention, relevance, confidence and satisfaction. The results of the interview analysis show that all four aspects were addressed in the pilot study, albeit to different degrees.

- Most references were made to the aspect of *satisfaction*, as in the following example: "[The students] enjoy it. They seem to enjoy it quite a bit." (P1,M1)
- Several statements also indicated that the respective app caught the students' *attention*: "When they came to the Augmented Reality the first time, they were like 'oh cool!'" (P1,F1)
- Fewer statements confirmed that the AR app helped enhance students' *confidence*, such as the following quote: "[I] can see that they're actually gaining in confidence." (P1,M1)
- Finally, a few remarks only showed that in some cases the apps stimulated the students' perception of *relevance*: "They really enjoyed the sense of beating back into the program with something that would've gone wrong. They almost felt a sense of ownership (laughing)." (P1,F1)

As a second relevant concept besides motivation, classroom engagement was included in the analysis. According to [27], students' classroom engagement can either be agentic (e.g., students ask a lot of questions and are explicit in their preferences and interests), cognitive (e.g., students use advanced learning strategies and actively steer their learning process), emotional (e.g., students display positive emotions and rarely express negative emotions), or behavioral (e.g., students work hard and show high persistence and effort).

- In the interviews, references to *emotional engagement* clearly prevailed with many teachers expressing that their students liked the app and showed positive emotions ("[The students] were all around the map in the chairs and yelling […] when they met this application [for the first time] and this is obvious that they […] have positive feelings"; P2,F1).
- Furthermore, some students showed *agentic engagement*, as the following quote implies: "When I used the flash card, a lot of students [said]: 'I want to try, I want to see what is done, what is the plan?'" (P2,F5)
- Also, teachers observed *behavioral engagement* in some cases: "[The students] were very hard working and they really wanted to do well, and they would keep inferring, they are very diligent. And when the app wouldn't work, they would keep trying, they had no problem logging onto another Ipad to try it again. […] They were really trying hard." (P1,F1)
- Only very few remarks showed that students were *cognitively engaged*: "[The students] were quite reflective." (P1,F1)

The third focus of the analysis of advantages refers to learning achievements on a procedural level. Various teachers' statements confirmed that the children…

- Generally learned something with the app ("they have learned something"; P2,F2),
- Learned faster than they would otherwise ("I saved [a lot of] time because I [taught] children the materials from four, five and sixth grade in two months. And in the normal activities, it took two months in 4th grade, two months in 5th grade and two months in 6th grade. Half a year in two months is [a] very good score"; P2,M4),
- Learned more actively ("they feel that the class were more active, they try a lot"; P2,F2), and
- Learned more easily ("So this is something […] new that they are curious [about], they want to learn and it's easy for them to learn about the new stuff that we're trying to teach them. So new approach, faster learning, simple"; P2,M2).

Apart from these evident advantages of using AR in class, the teachers described a number of further aspects which are all related to further contributions to teaching and learning processes. These aspects are:

- The advanced options for *3D visualization*: "There is the 'wow effect' because [students] can see something in 3D […], so it [is] completely different from just seeing images from the Internet or from the book" (P2,F4);
- The *adaptivity* of the concept to individual learning requirements: "It is another way of learning and it's a way of meeting the learning of so many different learning styles in the classroom" (P1,M1);
- *Collaboration* and a positive impact on the class atmosphere: "Students that are much better in using technology are [very] eager to help students that are not so good with the technology" (P2,M2);
- The advancement of students' *digital skills*: "They learn how to use technology" (P2,M2); and
- The up-to-date and *modern teaching methods* supported by AR: "It's good for learning because it's something new and then you have some new approach and a new way of teaching" (P2,M2).

The findings regarding the advantages of the educational use of AR are summarized in Fig. 2:

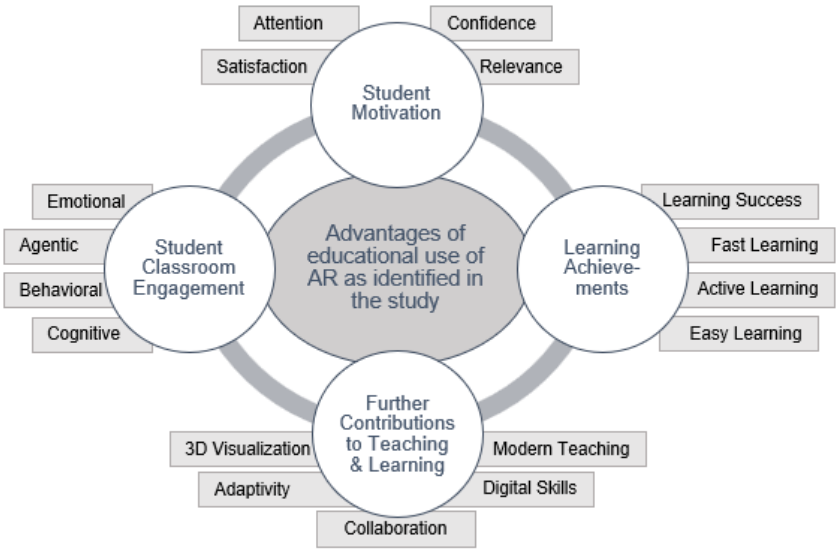

Figure 2. Advantages of the educational use of AR: Study findings summarized.

4.2 Problems and barriers to the educational use of AR

In the course of the interviews, the teachers were also asked about problems they encountered when including AR-enhanced apps into their teaching, and for barriers, they generally see to the integration of AR-enhanced apps into teaching and learning practices.

The responses can be grouped inductively into three main dimensions, which are 1) App and Technology, 2) Teachers and Students, and 3) The pilot study context. Aspects referring to the ARETE pilot (such as a lack of suitable materials, the timeframes for the piloting, or the testing necessary for participation in the study) are specific to the project and thus limited in their transferability. Hence, they are excluded from the following presentation. On the contrary, it is quite relevant also for related contexts to consider the aspects related to app and technology and to the stakeholders which will therefore be introduced in the following.

4.2.1 App and technology

All aspects mentioned in this category refer to problems caused by the design and contents of the app and by the use of technology in the pilot.

The three apps piloted in this study were tested at a developmental stage, hence bugs and technical issues caused delays in some cases. Teachers repeatedly mentioned *software issues* as the most dominant problem ("It was quite frustrating that people were constantly stuck and not able to progress"; P1,M1). Participants from one pilot, in particular, criticised the *app contents and the pedagogy behind the app* as a problem for its integration into classroom practice ("I think it has a lot of potential, definitely, but I think at the moment some of the activities are too confusing […]. Some of them seem a little overly challenging or a bit too complicated"; P1,F1). Other problems were reported in relation to the *app design and a poor user experience* in the app ("The delivery of the content would need to be in a clearer fashion so that the teachers understand straight off the bat what is expected of them and therefore what is expected of the students"; P1,F1).

Further app- and technology-related problems which were mentioned repeatedly refer to

- *An inappropriate curriculum fit* of the contents ("the contents in the geography app are very broad, very extensive. So we have to adapt the lessons because some contents belongs to higher courses and other ones are for lower courses"; p2,m3),
- *Issues with hardware* ("i found that most of our ipads are not compatible with the app"; p1,m1), and
- *Translations* within the app ("we had a lot of problems with translation. The translation of the app had a lot of mistakes"; p2,m1).

4.2.2 Teachers and Students

References in this category for teacher- and student-related issues were quite rare and many teachers also explicitly stated not to have encountered any problems in these contexts.

Problems with regards to students working with the app, which appeared only very rarely, include both *student behavior* ("Only one student [doesn't] want to be a part of it. They don't have a real reason, they don't know why, but they don't want to be a part of anything"; P2,M2) and *student skills* ("I think there are differences between the students that have a good ability with new technologies and the children that don't have it. Because children with tablets in their houses or computers, they do all the things faster and with more facilities than the other ones"; P2,M3).

Also in the case of teachers and teacher colleagues, single participants reported that there are problematic *teacher attitudes* ("Colleagues all the same […]: somebody said 'yeah this is great', but some of them [aren't interested in] nothing"; P2,F1) and that some teachers may be lacking the necessary *skills and knowledge* ("And I had constant emails texts from the teachers I support, you know, 'help me here'… 'help me there'"; P1,M1).

The teachers were also asked about potential problems with parents but did not describe any issues in this regard. It appears that the acceptance for using the AR-enhanced apps in the lessons was very high both with students and their parents: "Many students and parents […] from control groups were very disappointed because their children didn't use that application" (P2,F1).

The problems and barriers identified in the interviews are summarized in Fig. 3:

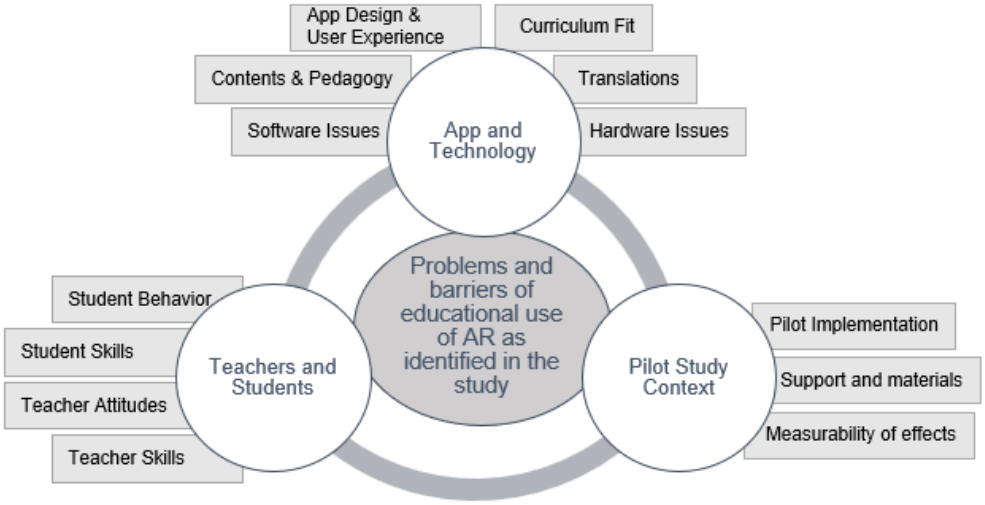

Figure 3. Problems and Barriers of the educational use of AR: Study findings summarized.

5 DISCUSSION AND CONCLUSIONS

Overall, the results of this study confirmed the advantages mentioned in other related sources, i. e., centrally the stimulation of students' motivation and classroom engagement and a faster, more active and easy learning experience. Further relevant advantages mentioned include visualization, adaptivity, collaboration, advancement of digital skills, novelty effect and modern teaching methods.

On the other hand, problems were reported on the level of apps and technology and, in some cases, on the level of teachers and students. The most frequently mentioned problems referred to the AR-apps with their software either not working flawlessly, missing content or presenting partly irrelevant or improvable content, or creating a poor user experience by their design. Students and teachers with their skills, attitudes and behavior were only rarely mentioned as problematic.

Certain limitations have to be considered in the context of these findings. Centrally, the piloting context of the ARETE project had a significant impact on the composition of the convenience sample. Only teachers with access to suitable technical equipment were admitted to participate. Furthermore, an analysis of technology acceptance and previous experiences shows that teachers in this self-selecting sample tend to have higher previous knowledge, higher technology acceptance and more positive attitudes towards technology-enhanced teaching and learning than average teachers [12], [28]. It is likely that some of the aspects mentioned would be considered or evaluated differently by another,

more representative sample. As an example, it is known from other studies that the availability of suitable devices and equipment as well as affordable software is a serious barrier to the implementation of digital media into classroom practices across countries [11], a claim which was naturally filtered from the pilot study through its design and recruitment process. Likewise, the missing ongoing support, education and professional development with regard to AR technologies [11], [18] was not a problem for the pilot teachers who received suitable support in the context of the intervention.

Another limitation refers to the methodology applied: the interview input is necessarily subjective and impacted by personal factors. Especially in the focus group, this may lead to a discrepancy between the number of mentionings of aspects and their relevance. To adjust the analysis to these methodological challenges, the results were summarized and presented according to their relevance but not quantified by the number of mentionings. Finally, the analysis of results needs to be reflected upon as the partly inductive procedure necessary to gather the individual responses naturally carries the threat of subjectivity in the analysis. For this reason, the coding process was conducted by two qualified researchers independently and the differences in the codings were reviewed carefully one by one and revised to achieve high objectivity and validity.

Against this background, it can be concluded that the study confirmed relevant previous findings from related studies while including a heterogeneous international sample. Qualified teachers were interviewed after extensive in-class experience with AR-enhanced apps. The heterogeneity of the sample with regards to national and institutional backgrounds indicates that certain advantages, but also challenges in AR-enhanced teaching and learning are perceived as relevant in different national and cultural backgrounds alike, even though the transferability to more average and non-constructed teaching and learning scenarios is still to be validated.

While the results presented confirm the general consensus that AR can support student motivation, engagement and learning achievements, it adds a new in-depth analysis of the constructs of motivation and classroom engagement which helps to understand the impact AR apps can have on students. With regards to motivation, a consideration of the sub-dimensions as described by [26] reveals that according to the teachers, the motivational effect of AR-enhanced apps mainly builds on the attraction of satisfaction and, to a smaller degree, of attention, but less strongly so on addressing students' confidence and feeling of relevance. This is understandable given the predominant association of AR apps with concepts such as "fun" and "curiosity". At the same time, it is a valuable conclusion for teachers who want to integrate AR apps into their teaching that it might be useful to emphasize the relevance of the contents and to pay attention to their students' confidence to benefit from the full motivational potential of the app.

Likewise, the concept of classroom engagement is sometimes just included as a notion of students being active or "engaged" [13] but seldom differentiated and analyzed systematically. The analysis following the structure of [27] shows that the students' classroom engagement mainly builds on an emotional type of engagement; this is in accordance with the results from the analysis of motivation. On the other hand, it has become obvious that teachers in this study hardly ever mentioned cognitive engagement, i.e., students applying sophisticated learning strategies [27]. This finding implies that for the integration of AR-enhanced apps into teaching and learning processes, it is particularly important to support students in the development of adequate and advanced learning strategies and meta competencies because the impact of the app on this area appears limited, according to the pilot teachers in this study.

Overall, the study presented offers strong evidence of the pedagogical value of AR-enhanced learning apps for teaching and learning processes. At the same time, it points to central barriers for the educational adoption of AR technologies that, in the context of the pilot study researched, mainly refer to inadequate software. In the context of the respective research findings summarized above, it becomes evident that further development needs to be done especially on the side of AR-enhanced learning applications, but also in contexts of teacher education and in educational practice at schools to ensure that all students can take full benefit from the rich potential that AR technologies offer for teaching and learning.

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