Potential vs. Practice: Challenges for the Implementation of Augmented Reality for Learning and Training in Practice

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Abstract: Augmented Reality (AR) holds many potentials for learning and training in organizations. However, there are surprisingly few examples that show an implementation of these potentials in practice. Motivated by this insight and similar observations through discussions with practitioners, we conducted an interview study to explore the usage of AR for learning and training in practice. Our results show that there is little systematic and established use in practice because of several challenges inhibiting its use. Our paper reports on these and discusses how they might be overcome.

Keywords: Augmented Reality, Learning, Training, Interview Study, Challenges, Practice

1 Introduction

Augmented Reality (AR) superimposes digital content such as objects, text or other items onto the real environment [Az97]. By using AR technology, users find themselves in a mixed reality [MK94] with an environment made up of both, real and virtual components. AR has been adopted in many different sectors of work like manufacturing [Ab17], service and maintencance [Fa16], healthcare [Si17], sports [Pa18] and many others. One specific area of interest is its potential support for learning and training in organizations. While its potential for learning and training *at work* has been recognized (e.g., [Di13, Fu17, Ho17, Sa16]), there are surprisingly few reports on implementations of these potentials in practice. Motivated by this, we asked ourselves whether and to which extend AR is currently implemeted in practice as a learning and training tool as well as what success factors or challenges exisit.

The work presented here aims at answering these questions. We conducted an interview study with 44 representatives of organizations interested in using AR for learning and training, service providers offering corresponding solutions and researchers engaged in projects with that purpose. We surveyed them about current and former projects as well as factors that led to success or provided challenges. Most examples we were told about were in rather immature states, and we identified many challenges for the integration of AR into learning and training processes. By reporting on the gap between the potential of AR for learning and training and current implementations, our work contributes to the

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knowledge on implementing AR and tapping into its potential for learning and training.

2 Literature Review: AR for Learning and Training at Work

The potential of AR for learning is discussed by many researchers and practitioners. Compared to other media for learning, a substantial amount of this discussion has been held in the context of learning at work (as opposed to educational settings). There are many studies that show the applicability and the potential of AR for learning that is integrated into the workplace [Li17, Ni17, Ul16]. Among the available studies, AR has been shown to improve attentiveness, motivation and internalization of knowledge [Di13, Sa16], to ease the learning of standard procedures [Si17], to help people reproduce knowledge later on [Fu12], and to increase the confidence about one's own learning [Di13]. One specific promise that AR holds for learning is to bridge the gap between the (often theoretical) learning and the (practical) application of what has been learned [Ho17], which is crucial for the transfer of learning into practice [Ki75, Ph96]. As a consequence, AR is often used for learning or supporting practical work tasks [Ab17, Bü17, Mo17]. By using it for tasks like vocabulary training [Sa16] or simulating medical tasks [Az18, Si17], AR support more sustainable learning [Bo14].

Recent work on the application of AR for learning shows mixed results. Funk et al. [Fu17] found that projection-based AR is helpful for learning manual tasks. Radu and Schneider [RS19] show that learners arrive at a better understanding of physics when using AR. While these studies stress the potential of AR for learning, other work has arrived at less encouraging results. For example, Wilschut et al. [Wi19] found no significant differences in time or learning effects when comparing screen instructions to AR projection-based instructions for manual assembly tasks. Also, a study of Büttner et al. [Bü20] finds AR to be inferior to face-to-face trainings, only showing an advantage of preventing mislearning when compared to paper manuals. Werrlich et al. [We18] report similar findings.

Recent studies also point to the fact that despite its potential, there are only very few implementations of AR based learning and training in practice [Du18], and that its success and acceptance depends much on the (perceived) value added by such training [Ko18] as well as on the implementation of AR along established learning theories [Zh14].

3 Interview Study: Challenges of AR for Learning and Training in German-speaking countries

Looking at the potential benefits of AR for learning and training portrayed in the previous chapter, one may assume that AR is already an established tool for learning and training in practice, or at least rapidly emerging for these purposes. Surprised by a lack of evidence and only very few insights into practical applications, we wanted to investigate the actual use of AR for training and learning in practice including benefits, potentials, disadvantages

and challenges of its implementation. In order to acquire an overview over the current situation and its state of implementation, we conducted an interview study with different actors that have some experience on applying AR for learning and training. In the interview, we asked questions based on the following research questions:

1. How is AR being used in practice for learning and training?
2. What challenges are being faced regarding this usage in practice?

We restricted our study to German-speaking companies in order to simplify differences.

3.1 Study Design

Procedure

Based on a thorough internet research, 255 German-speaking actors were identified to have some experience in using AR for learning and training. These contacts were investigated in order to determine their suitability and willingness to participate in our study. Out of these, we interviewed a total of 44 representatives from companies out of various fields of work (e.g. automotive or education). From July 2018 to December 2018, each interviewee was called for a 45 minutes long semi-structured interview by one of three researchers. Afterwards, all recorded audio files were transcribed and analyzed using a mixed content coding approach. First, three researchers marked all passages in line with our research questions with associated codes. Second, we reviewed these codes in detail with an inductive bottom-up method and analyzed resulting sub-codes.

Participants

Taking a closer look at the actors that were interviewed, we observed three major groups differing based on their perspective on AR as part of learning and training:

- **Service providers** use AR to support training and teaching services they offer to other companies. Though, they rarely use the technology for their own employees. (n = 17)
- **Users** apply AR tools for teaching and training their own employees. (n = 15)
- **Researchers** are focused on researching the benefits and challenges of AR for learning and training of students and employees as part of funded projects. (n = 12)

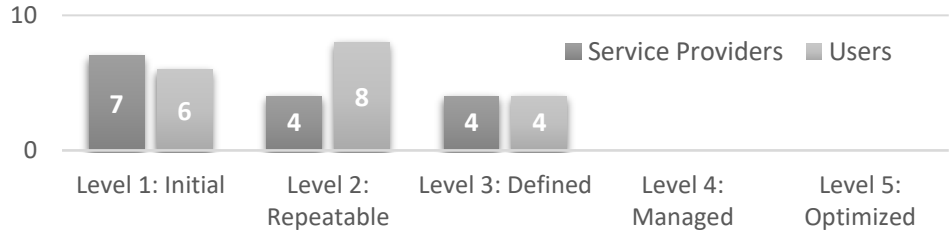

Fig. 1: Maturity levels of applications used in practice by service providers and users who took part in our interview study (n = 33). Levels are based on capability maturity models [Ma10, Pa93].

Challenges regarding…	abs. #	rel. %
Adoption and Acceptance	147	43%
Openness towards technology	62	42%
Recognition of added value	26	42%
Frustration of certain groups	21	34%
Fears about adopting	15	24%
Usability	46	31%
Low level of comfort	36	78%
Getting along with the system	6	13%
Resilience of users	4	9%
Integration in processes	29	20%
Exclusion of certain communities	10	7%
Finance, Training, Infrastructure	90	27%
Financing	30	33%
Training of employees	19	21%
Availability of hardware	13	14%
Internet coverage	12	13%
Industry sector specific issues	10	11%
Provision of 3D data	6	7%
Hardware and Software	45	13%
Limited hardware	20	44%
Realistic representation	12	27%
Limited software	9	20%
Complex setup	4	9%
Uncertainty	35	10%
Future impact possibilities	16	46%
Unknown area of expertise	14	40%
Unknown risks	5	14%
Responsibility and Security	22	6%
Responsibilities	11	50%
Security	4	18%
Ethical guidelines	4	18%
Privacy	3	14%

Tab. 1: Absolute numbers and relative frequencies of mentions for each group of codes and their respective sub-codes. The percentages always add up to 100% within each group.

3.2 Study Results

In this section we report on the dissemination, implementation in practice and challenges of AR for learning and training. After an overview over the current states of implementation, we present challenges that most likely have led to these states. In what follows, we focus mainly on the results gained from interviews with service providers and users (see above), as researchers often reported on prototypes rather than implemented

solutions and would hence bias the results. Among the challenges reported by our interviewees, we identified five different groups of challenges (see Tab. 1). These different groups will be described in order of their total amount of mentions and supplemented with their relative frequencies. Corresponding quotes were translated from German to English.

Implementation and Maturity Level of AR for Learning and Training in Practice

The interviewees (only service providers and users) mentioned 64 unique examples of applying AR for learning and training in practice. Half of these were only mentioned briefly or in a state of ideas rather than actually being implemented. To understand the current state of applications, we focused on examples described in more detail and analyzed their maturity. Based on capability maturity models in general [Pa93] and in the context of e-learning [Ma10], we assigned them to levels of maturity. As Fig. 1 shows, we had enough information on a total of 33 application examples from service providers and users. The figure also shows that the majority of projects remain on initial steps with only prototypical use (if at all, level 1) or very initial usage by only a few users (level 2). Only eight projects fell into the category of defined applications that are systematically used for a small purpose (level 3). To our surprise, we did not find any reports on applications that reached a level above level 3 showing that their current state is still quite immature.

Challenges: Adoption and Acceptance

When asked about challenges, the interviewees most frequently mentioned acceptance and adoption (about 43% of total mentions). On a closer look, interviewees therein described the openness towards the new technology (42%) and its usability (31%) as challenges. Others mentioned the integration of AR into processes (20%) as well as the exclusion of specific communities (e.g. visually impaired people, 7%).

Regarding acceptance, participants stressed the need to ascertain and communicate the added value of AR (42%): *"So, you need to know, to spark everyone in the company, […] we created a demo that presented all the different things that could be possible with this technology." (user)*. Interviewees also reported on people having issues with or fears about adopting AR (24%): *"If people have no idea about the interactions, these people won't put it on because of fear. They don't want to embarrass themselves." (service provider)*.

Regarding the usability of AR, participants stated that they experienced a rather low level of comfort interacting with the hardware (78%) and issues getting along with provided software systems (13%). Regarding the comfort, we were told that *"a general challenge is a) when doing that for a long time and having those glasses on for like over half an hour or something, then you will notice a difference. One needs some time to calm down [afterwards]. The second thing is just the temperature. The temperature underneath those glasses." (service provider)*. People also explained that when talking *"[…] with firefighters, students and also participants, who tried those things, it still seems too new. It is too complex for now. It is too difficult to handle. Especially, we realize it when people have – I'd say – no experience with computer games or something like that. They basically have a bunch of problems interacting with the system." (researcher)*. In this context, it

was sometimes assumed that young people might adopt AR easier because of their affinity towards technology: *"I believe that young people like our trainees about 22 or 23 years old and older are quite good with technology. They are fairly open to play with it, like just using it. That's why I don't really see a problem there." (service provider).*

Challenges: Finance, Training, Infrastructure

Regarding finances, training and infrastructure as prerequisites for using AR, participants pointed at issues about their ability to roll out and use this technology at all (about 27% of all mentions). More specifically, a lack of knowledge on training of employees was mentioned often (21%). This was reported for both employees and trainers: *"In order to have trainees acquire those competences, the trainers need to be trained. And that's what we are doing right now. But how do you teach [them] to impart AR?" (service provider).* In addition, some participants reported that they could not provide essential prerequisites like Wi-Fi access for AR devices (13%): *"So, when I look at the Wi-Fi connection at our project partners, well, then I guess this might take like ten, fifteen years" (researcher).* Also, the scarce availability of AR-devices was mentioned (14%). Some users stated that they only possessed a low number of devices that still take up a lot of work: *"Because I still have one device, I still have to/still need to ensure that it is always up to date. Eventually, you need to service it at the customer by the guys in our IT department, and somebody has to take care of that. And for some people this is just an 'Oh, gosh. Not this as well on top.'-reaction." (service provider).* Others told us that this was likely to improve, as companies seem to be more willing to offer funding for AR (33%). Although the acquisition cost has been decreasing, making devices more affordable, "*[it] is still relatively high"* and does not incorporate additional costs: *"I not only need to get the hardware. Most likely that is the smaller problem, but rather I need to change my way of working and everything that has to do with changing habits" (service provider).*

Challenges: Hardware and Software

Regarding the capabilities of AR hard- and software (13% of total mentions), many participants pointed at the limited features and sensors of the hardware (44%). These remarks were specifically aimed at current head-mounted displays (HMD): *"I would just say that technically speaking, we are currently reaching the limits of the HoloLens regarding its abilities and features: Voice control, speech output, gesture control, object recognition." (user).* People also mentioned other limitations such as resolution, GPS accuracy, field of view (FOV), cable management or gesture recognition. For many, this made the hardware seem to be insufficient and not close enough to be an authentic integration of reality and virtuality (27%), resulting in issues similar to the uncanny valley effect [SN07]: *"[We need something] Where you are training dialogue options and where you can see each other, not some other avatar in front of you. Although it might also be talking to you, it looks way different than the actual person behind the voice. […] And when it is all about having a serious talk with someone to clarify a difficult situation where a conflict or something of that kind is going on […] then people want to see gestures and facial expressions" (user).*

Some interviewees also remarked that the setup was too complex (9%) reducing the utility for spontaneous sessions: *"Now, looking at the Microsoft HoloLens for example, there is a complete Windows-PC on it, which means that I have do more or less my complete Windows-Login and boot and start and open the app and all of that until I eventually can use my e-learning software. These are all very time-consuming steps that need to be shortened, so that a user is able to reach the contents it's all about way faster." (service provider)*. In addition, many existing applications are mostly prototypes or work in progress, excluding them from any safety critical system (20%): *"[The tool] was about pacemakers and interacting with them by using an app. […] And two years ago, there was a case that a hacker group thought they are going to do something fun and were sending everybody using these pacemakers a pushup notification […] and told them 'Hey, if you are not paying, we will turn your pacemaker off.'" (user).*

Challenges: Uncertainty

Uncertainties around AR amplify concerns on its added value (10% of total mentions). While there is a number of scenarios on how AR may impact the future, it is unclear to participants how this technology will affect their work (46%): *„So, this is not really so heady that one can actually say something. It still doesn't grow on me why I should put on those helmets. Same for Virtual Reality. It is possible to do it nowadays […]. But regarding learning situations, it is not tested enough and still in the fledgling stage." (researcher)*. As a consequence, participants are concerned about being exposed to a new and hence unknown situation (40%) and thus commented on probably facing unforeseen risks (14%): *„Mainly, it is this fear of being overwhelmed by the technology. I believe this is the root of it and along with-it additional overhead that they later on can't compensate for with these new possibilities." (service provider).* These factors make it especially difficult for service providers to convey its added value regarding learning and training.

Challenges: Responsibility and Security

Regarding the usage of AR in practice (as opposed to trials and prototypes), additional concerns were raised (about 6% of total mentions). Some interviewees felt that legal responsibilities of using AR devices are quite uncertain, especially if users are being guided by AR (50%): *"Who is going to be responsible when a user is really just doing what he is told by those glasses and something happens while doing that? There, I see a huge problem regarding legal stuff." (user)*. In case of system failure resulting from malfunctions, we were told that laws are only starting to be discussed, adapted or implemented, if at all. Adding to this, some mentioned that ethical guidelines are still missing (18%): *"When I for example simulate a machine like a saw or something and put a piece of wood in there, can I cut of my hand with it? Or how will it work when I do something wrong? […] If the engineers that develop this today have no idea about learning, this is sadly quite a high responsibility that [designers and providers] currently have to carry." (researcher)*. Interviewees also mentioned privacy problems through recordings and data analysis of employees for optimization reasons as unsolved (14%). Lastly, the reveal of corporate secrets and other sensitive information is a challenge

mentioned by participants (18%): *„So, the water supplier didn't want to hand over the plans for the drinking water pipelines because of information security and safety reasons. Because they think that at two or three locations, when you know them, you can bring down a whole city with poison. Or – I don't know –, maybe use explosives to destroy something. So, working with actual data is going to be difficult in some cases." (researcher).*

4 Discussion

The insights provided by the interviewees show that despite its potentials – which initially caused them to engage with AR for learning and training – there are only a few applications of AR for learning and training outside the status of research projects. In our sample, many of these applications were in rather immature stages. This is also reflected in challenges related to insufficient hard- and software or the value added. The latter challenge in particular suggests that there is a discrepancy between expectations or assumptions and ways to implement these potentials in practice.

Some of the challenges may be overcome with systematic measures or over time, while others depend on additional factors. In the interviews, we could identify a tension between the questions about value added and the cost and availability of devices: As long as there is no clear value added, financial investments are low and hence availability will be slim. However, the other way around, if there are no devices available, it will be hard to investigate value added beyond small installations and prototypes. This, in turn, may also explain the low overall maturity of projects reported on by our interviewees (see Fig. 1). Additional uncertainties about developments around AR as a new technology amplify this. To break this tie, we need leading themes or best practices through which we can show how a systematic use of AR enhances learning and training success compared to other currently used means. We also need ways to analyze and communicate its potential value added and identify how to continually achieve it. Communicating good practice examples of AR (including a proof of their value added) as well as ways for training people to understand and use the technology and its potentials for their work could be viable steps towards a solution. They may help reduce reluctancy and solve issues for adopters with little technological affinity by showing how benefits may outweigh existing concerns. In contrast to these challenges, problems such as lacking comfort when wearing an AR HMD, limited software and hardware support or problems in handling AR devices may diminish over time as AR continues to be researched, implemented and used. In a similar vein, issues of IT security can (in general) be solved by manufacturers of hardware and providers of software as soon as the demand increases and know-how is established.

From a different perspective, some of the challenges point at a lack of readiness for the application of AR in practice. Challenges such as how to train coaches or the lack of Wi-Fi connectivity suggest that many companies that could benefit from AR for learning and training may lack important prerequisites. If there are no coaches capable of teaching

employees on how to use AR, it will be difficult to roll out corresponding solutions. Likewise, a lack of Wi-Fi connectivity will directly translate into a lack of feasibility if digital tools are to support existing workflows. One may argue that companies that are already using AR may not have the resources to provide infrastructure or training for employees, but the fact that these issues were also mentioned by service providers, who offer AR based trainings, shows how important it is to focus on readiness. Complemented by insights regarding information security and data usage, these are issues to be solved in order to make users and services providers ready to use AR for learning and training.

There are also challenges concerning the responsibility and ethics of being guided by AR. Both are areas that currently also come up with technologies such as artificial intelligence. This shows how important it is to deal with them intensively and to come up with clear rules and norms. However, it is surprising that despite the importance and prevalence of these questions in German-speaking countries, they were mentioned less frequently than other challenges (6% total). This may indicate that we are currently too far away from implementing AR in practice, rendering these questions as unimportant for now.

Overall, our interview study shows that there is great interest in applying AR for learning and training. We could identify a large number of potential interviewees working in this area, and we received rich descriptions of ideas and applications. However, our study also clearly shows that besides its potentials, the implementations of AR in practice are in a rather immature stage, and that there are still several challenges that need to be overcome. Since some of these challenges are on a very basic level, this underpins the notion that there is still a lot of work to be done until AR becomes and established medium for learning and training in companies. The differences between expectations and questions or issues regarding added value, usability, adoption and others suggest that there is a need to find better ways of implementing potentials in practice. Because many currently available studies look at short-term (lab) studies, we need to show how AR unfolds long-term potentials and, thereby, justifies investments into hardware, software, infrastructure and training needed for its implementation in practice. Research may add to this by looking at and reporting on the benefits from long-term usage of AR for learning and training.

5 Limitations

There are certain limitations that need to be recognized. First, the study builds on 44 volunteer interviewees from the areas of research, user organizations and service providers. They have been recruited from nearly 300 candidates and represent a good bandwidth of relevant actors. A study like this, however, is necessarily limited to a certain set of participants. Second, a study like this leaves little room for scrutinizing the statements and opinions we were told, leaving alone any chance for measurements or the like. However, we found many interviewees to mention similar aspects and challenges suggesting that these are present in many cases. In addition, the fact that very few interviewees mentioned established practices of AR for learning and training in practice

at all (cf. Fig. 1) suggests that there are only a few, if any, as it is very likely that we would have been told about successful cases first and intensively. Third, the study relies on information provided voluntarily by the interviewees without our knowledge of whether they have been withholding information. Despite these disadvantages that are inherent to interview studies, we are convinced that our work provides relevant insights into the use of AR for learning and training in practice. Interviews provide the opportunity to dive deep into experiences and challenges while providing good examples of what is happening.

The study presented here was conducted in late 2018, which on first sight may seem like it is slightly outdated. However, many devices such as the HoloLens are still state of the art and most issues and challenges found in the interviews are still valid to this date as we have been told by partners. Therefore, we consider the study to be very up-to-date and to present issues that need to be worked on in order to tap into the potential of AR for learning and training in practice. Since the interview study itself only focuses on companies in German-speaking countries, statements about the international situation of AR regarding learning and training in practice may be inappropriate. Regardless, in our work, we discuss challenges faced by a number of companies in an economically important country.

6 Conclusion

In our work, we present potentials of AR for learning and training based on current research and contrast these findings with results of an interview study conducted with 44 participants from German-speaking companies. While literature shows benefits for AR in learning and training, we asked participants about their experiences with AR. Based on these answers, we discovered that many AR applications for this purpose are still in an early stage and, hence, rather immature. Also, we were told about a number of challenges still being faced when implementing AR in companies. However, besides challenges like uncertainties regarding the value added, a lack of provided infrastructure, hard- and software limitations and the absence of know-how and legal norms, our study shows that AR is considered relevant for learning and training in practice. In order to further increase the maturity of applications and provide insights on the long-term values added, challenges and benefits need to be compared and systematically worked on, especially in long-term studies. This way, more companies could be willing to invest in implementing this technology and training users.

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