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Benefits of Augmented Reality in Educational Environments – A Systematic Literature Review

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Abstract. By augmenting the real world with virtual information, Augmented Reality (AR) provides new possibilities for education. Although AR is frequently applied in educational environments, the value of AR applications in these environments is not yet investigated in its entirety. Additionally, educators face different directions of AR applications, which may differ regarding their potential benefits. To help overcome these challenges, we conduct a systematic literature review to synthesize a set of 25 publications. We identify 14 different benefits and cluster these into six different groups. We use the Five Directions of AR in educational environments by Yuen et al. [1] to further detail possible benefits for different directions of AR applications. Our findings indicate that specific directions of AR applications are more likely to lead to certain benefits such as increased motivation. Future research is needed to investigate the causality between benefits and directions of AR in more detail.

Keywords: Augmented reality, education, benefits, literature review.

1 Introduction

Bridging the gap between the virtual and the real world, Augmented Reality (AR) provides new ways of teaching and learning, which are increasingly recognized in research [2]. Although AR is one of the most emerging technologies in education these days [3], the value of AR in learning environments remains unclear [2]. Furthermore, various types of AR applications exist in educational environments, which may differ regarding their benefits towards educational outcomes [1]. For the context of this paper, we refer to *educational environments* as any scenario, in which people are acquiring knowledge in a structured and controlled process.

While recent studies have investigated the use of AR in educational environments [2, 4], a systematic analysis of AR benefits is yet to be accomplished [2]. A first publication exists, identifying positive and negative effects of AR in educational environments [5]. Due to missing information concerning the applied methodology, we were not able to reproduce the study. Previous research does not consider the different

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types of AR applications in educational environments. To close this research gap and advance the field of AR, we pose the following two research questions:

1. *Which benefits do AR applications provide in educational environments?*
2. *How do these benefits differ regarding different types of AR applications?*

For the purpose of answering these questions, we conduct a systematic literature review to identify and analyze relevant publications. Additionally, we cluster relevant publications with regard to the applied type of AR based on the Five Directions of AR in education proposed by Yuen et al. [1].

An overview of AR benefits in educational environments regarding different types of AR applications helps educators to decide whether the implementation of AR is reasonable in certain educational scenarios. Moreover, our study identifies gaps in current research and thus guides future studies within this domain.

This paper proceeds as follows. Section 2 introduces the AR concept and describes AR's Five Directions in educational environments [1]. We then describe our systematic approach to identify and analyze previous literature in Section 3. In Section 4, we present the identified benefits of AR in educational environments and map the related studies to the Five Directions in Section 5. We discuss our findings in Section 6. Our paper ends with a conclusion for research and practice in Section 7.

2 Augmented Reality in Educational Environments

2.1 The Concept of Augmented Reality

Although the term Augmented Reality was coined by Tom Caudell – a former Boeing researcher – in 1990, the concept of augmenting the real world by virtual data was initially used by a number of applications in the late 1960s and 1970s. Since the 1990s, AR was used by some large companies in purpose of visualization and training. Nowadays, the rising power of personal computers and mobile devices enables the concept of AR to be applied in traditional educational environments such as schools and universities [3].

During recent years, AR has been given different meanings [2]. Milgram et al. [6, p. 283] define AR based on the reality-virtuality continuum (Fig. 1) as "augmenting natural feedback to the operator with simulated cues". The reality-virtuality continuum allows distinguishing between the concept of AR and concepts such as Virtual Environments (also known as Virtual Reality (VR)) and Augmented Virtuality (AV)). While VR deals with settings where "the participant observer is totally immersed in a completely synthetic world" [6, p. 283], AV is concerned with environments in which "the primary world being experienced is in fact [...] predominantly 'virtual'" [7, p. 4] and augmented with information from the real world. Additionally, Milgram et al. [6, p. 283] mention a more restricted definition where AR is seen as "form of virtual reality where the participant's head-mounted display is transparent, allowing a clear view of the real world".

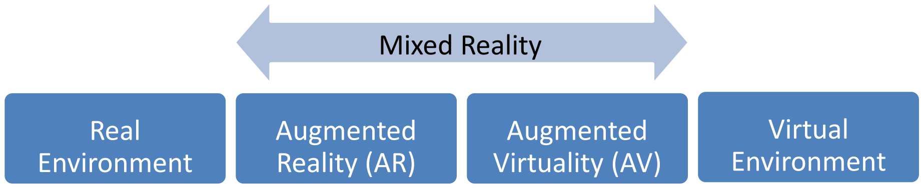

Fig. 1. Reality-Virtuality Continuum [6]

In line with Wu et al. [2], we do not believe, that AR is restricted to any type of technology. Accordingly, we broadly define AR as "a situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information" [8, p. 205] and consider AR as a concept which is conceptualized beyond technology. Nevertheless, its realization depends on modern technology.

2.2 Five Directions of Augmented Reality in Educational Environments

Different ways exist to implement AR in educational environments [1, 4]. The Five Directions by Yuen et al. [1] enable a classification of AR applications into five groups as follows.

Discovery-based Learning. AR can be used in applications that enable Discovery-based Learning. A user is provided with information about a real-world place while simultaneously considering the object of interest. This type of application is often used in museums, in astronomical education, and at historical places.

Objects Modeling. AR can also be used in Objects Modeling applications. Such applications allow students to receive immediate visual feedback on how a given item would look in a different setting. Some applications also allow students to design virtual objects in order to investigate their physical properties or interactions between objects. This type of application is also used in architectural education.

AR Books. AR Books are books which offer students 3D presentations and interactive learning experiences through AR technology. The books are augmented with the help of technological devices such as special glasses. The first implementations of AR Books show that this kind of medium is likely to appeal to digital native learners, which makes it an appropriate educational medium even at the primary level.

Skills Training. The support of training individuals in specific tasks is described by Skills Training. Especially mechanical skills are likely to be supported by AR Skills Training applications. Such applications are, for instance, used in airplane maintenance, where each step of a repair is displayed, necessary tools are identified, and textual instructions are included. The applications are often realized with head-mounted displays.

AR Gaming. Video Games offer powerful new opportunities for educators which have been ignored for many years [9]. Nowadays, educators have recognized and often use the power of games in educational environments. AR technology enables the development of games which take place in the real world and are augmented with virtual information. AR Games can give educators powerful new ways to show relationships and connections. Additionally, they provide educators with highly interactive and visual forms of learning.

3 Systematic Literature Review

We applied a four-step research approach. We (1) identified relevant publications. We then analyzed the identified publications by (2) coding and (3) grouping benefits as well as (4) mapping the related studies to the Five Directions.

3.1 Data Collection

For the identification of publications addressing AR in educational environments (Fig. 2), we applied a systematic online literature database search. We included databases related to the information systems discipline (IEEE Xplore (IEEE), ProQuest, AIS Electronic Library (AISeL), and ACM Digital Library (ACM)) as well as more general databases (EBSCO Host (EBSCO) and ScienceDirect). Potentially relevant papers needed to match the following search pattern in title, abstract, or keywords: (“Augmented Reality” AND (“Educat*” OR “Learn*” OR “Teach*” OR “College” OR “School”) AND (“Benefi*” OR “Advantage*”)). Our search yielded a total of 523 articles. The publications were analyzed with regard to our inclusion and exclusion criteria (Tab. 1).

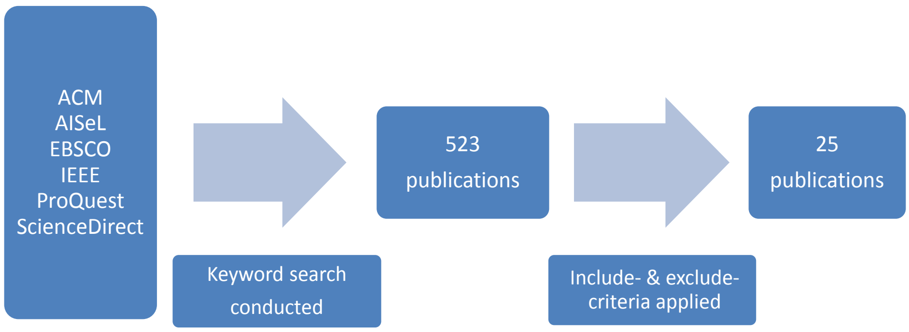

Fig. 2. Research Approach: Data Collection

Table 1. Include and Exclude Criteria

Include Criteria	*Exclude Criteria*
Empirical works	Theoretical works
A teaching problem is solved with the help of AR or a teaching concept is improved by AR	Untried or untested technologies
Lists positive effects of AR applications in comparison to conventional learning tools	No comparison to conventional learning tools
Human learning	Machine learning
English language	Other languages
Peer-reviewed	Not peer-reviewed
Students without special requirements	Students with special requirements

We limited the results to empirical works since we aimed to gain insights into benefits of applied systems and benefits in real-world scenarios. Additionally, we aimed to ensure, that the benefits we found were not only results of theoretical thoughts, but proved in real-world scenarios. Whereas some papers reported negative effects (e.g., ineffective classroom integration), we focused on positive effects due to their predominance in research studies and in order to analyze the interdependence of these positive effects. Moreover, we excluded non-human scenarios like machine learning and learning contexts with special requirements like students with handicaps. Both aspects were left out since they deal with specialized context that may provide benefits which cannot be transferred to a general context without additional validation.
Each article was read by two of the authors. In case of divergent classifications, the authors reasoned until agreement was reached. After merging our results, a total of 25 articles remained. All relevant articles describe experiments, which were conducted in order to investigate the benefits of AR in comparison to conventional learning tools. They are printed bold in the reference section.

3.2 Data Analysis

Our data analysis is illustrated in Fig. 3. First, we assigned articles to one of the Five Directions. The definitions proposed by Yuen et al. [1] include characteristics for each direction, which we matched to the reviewed articles. Two authors independently assigned each article to one of the Five Directions and subsequently compared their assignments. In case of divergent assessments, the authors reasoned until agreement was reached. The according inter-coder reliability [10] – calculated by dividing the number of initial agreements by the total number of initial agreements and disagreements – amounts 0.64 (cf. our discussion of this score in Section 6). During the assignment, we collected information about the mentioned benefits and merged similar benefits into a single one. To improve clarity and to find semantically coherent groups, the benefits were clustered into categories if they were logically related to the same subject. We followed the theoretical approach of clustering proposed by Jankowicz [11]. After the assignment of a direction to each article, we counted the occurrences of each benefit found in the articles for each direction. A total of 67 benefits were identified, containing 14 unique benefits, which were clustered into six clusters. In the next chapter, we describe the groups and related benefits.

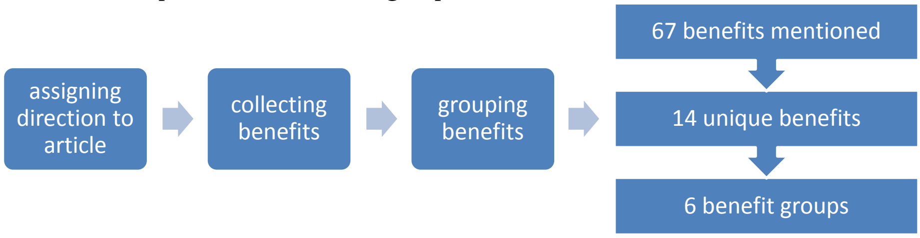

Fig. 3. Research Approach: Data Analysis

4 Benefits of Augmented Reality in Educational Environments

In this section, we present the groups of benefits as well as single benefits, which we identified and describe them by citing examples from the reviewed literature.

4.1 State of Mind

Increased Motivation. By Increased Motivation, we refer to users being more eager, interested, and engaged to deal with new technology as well as teaching and learning content compared to non-AR (NAR) methods [12–24]. The benefit is described in quotations such as “the AR-style game play successfully enhanced intrinsic motivation towards the self-learning process” [13, p. 113], “Participants using the AR books appeared much more eager at the beginning of each session compared with the NAR group” [12, p. 112], and “students have been satisfied and motivated by these new methodologies, in all cases” [19, p. 60]. The benefit can be further described by findings such as the users being “more proactive” [25, p. 10, 26, p. 187] or the will to continue learning using the AR technology after class. A more detailed description was found in Iwata et al. [13], where physical interaction is explicitly identified as a driver to enhance emotional engagement.

Increased Attention. This benefit is about the attention users pay to the technology and thus to the teaching and learning content. It is mentioned explicitly by Vate-U-Lan [20]. In two other cases, we interpreted the quotations “felt it interesting [...] using the AR-guide system” [27, p. 194] and “teachers noted that the smartphones [the AR-System] promoted interaction with the pond (of which the pupils should learn something about) and classmates” [14, p. 552] as indicators for increased attention.

Increased Concentration. This benefit concerns users' concentration while using AR applications. Similar to the detailed description for Increased Motivation through AR application in Iwata et al. [13, p. 9], "physical interaction induced deeper concentration [...]".Yen et al. [21, p. 173] and Ibáñez et al. [24, p. 11] perceive a "higher [...] degree of concentration" or a "higher level of concentration".

Increased Satisfaction. Increased Satisfaction means that users experience higher satisfaction regarding the learning process or their educational progress, that is, regarding the learning process, students have more fun running through a library and solving tasks directed by an AR application than by a librarian [28]. Martín-Gutíerrez et al. [17, p. 6] state that "the students were quite satisfied with the [AR-]tools used to learn". A reverse statement is that the frustration level is higher using the manual way [23]. This benefit is also mentioned by Ibáñez et al. [24] and Redondo et al. [19].

4.2 Teaching Concepts

Increased Student-centered Learning. Student-centered Learning is a teaching concept in which conventional lectures are replaced by new active and self-paced learning programs. In Student-centered Learning approaches, students are more self-responsible for their own progress in education, and educators act as facilitators who enable the students to learn independently and individually. Three studies report that AR enabled an increased Student-centered Learning in the regarded learning environment. Vate-U-Lan [20, p. 894] recognizes that the regarded AR application enabled the tailoring of functionality to student's learning capabilities. Similarly, Kamarainen et al. [14, p. 554] report that "these technologies provide ways of individualizing instruction in a group setting" and that "the technology supported independence" which "freed the teacher to act as a facilitator". Furthermore, Liu et al. [15, p. 173] report that AR "improves the ability to explore and absorb new knowledge and solve problems", indicating that AR can support Student-centered Learning environments as students are enabled to explore knowledge and solve problems autonomously. These studies show that AR can support a Student-centered Learning approach by providing educators with new possibilities to individualize their lessons according to students' capabilities and by enabling students to learn more independently from educators.

Improved Collaborative Learning. Three studies report that the analyzed AR applications improved collaborative learning by providing new ways of communication and cooperation. Wang et al. [29, p. 57] regard their AR application as "effective environment for conducting collaborative inquiry learning activities". Other authors join the observation of Improved Collaborative Learning as they highlight "the opportunity for collaborative communication and problem-solving among students that arose from the augmented reality experience" [14, p. 552] and the "facilitation effects of AR technology on collaborative learning effectiveness" [22, p. 322].

4.3 Presentation

Increased Details. In the context of urban design education, the tested AR "has more detailing particularly in the texture of models" [27, p. 17] compared to the traditional use of wooden block models.

Increased Information Accessibility. AR applications can improve and ease the access to information regarding teaching and learning content. In the context of an assembly task guided by an AR application, Hou et al. [23, p. 447] report that "AR eases information retrieval". Additionally, Iwata et al. [13, p. 112] mention that "superimposed information was nicely integrated and did not interfere with the learning process" while learning a traditional Chinese board game.

Increased Interactivity. This benefit is about new ways of interaction with the learning tool, through concepts such as context-aware information on the device. Increased Interactivity can be seen as precondition for other presented benefits. However, Increased Interactivity through the application of AR is a characteristic which is not realized by conventional methods [12, 24] and is therefore specified as an individual benefit. Dünser et al. [12, p. 113] state that "[i]nteractions in AR engage learners with the content, and allow for knowledge to be acquired through their [the students] own manipulation of content [...], as supported by constructivist learning theory". While Increased Interactivity can also be related to teaching concepts, it mainly focusses on technology enabling interactivity rather than the educational decision for interactivity.

4.4 Learning Type

Improved Learning Curve. An Improved Learning Curve effect refers to students learning faster and easier with AR applications compared to non-AR applications. Liu [30, p. 525] reports that "tests taken by the [AR application users] in all the learning activities were significantly better than those of the [traditionally learning users]". Similarly, Chang et al. [25, p. 193] state that "[t]he AR-guided group had better learning effectiveness" as well as "[t]he learning performance of the AR-guided group was thus superior to that of the other two groups". Similar observations have been made in multiple studies [14–16, 19, 22–24, 26, 31–33].

Increased Creativity. AR supports creative learning as observed by Chang et al. [25, p. 194]. Additionally, Liu et al. [15, p. 173] found that "[AR] also improves student creativity and the ability to explore and absorb new knowledge and solve problems". Vate-U-Lan [20, p. 894] reports that AR "highlighted many benefits that include [...] integration of a variety of learning skills such as [...] creativity".

4.5 Content Understanding

Improved Development of Spatial Abilities. Our research indicates that with the help of AR, students are able to acquire a new level of spatial abilities. Dünser et al. [12, p. 112] mention that their "results support the hypothesis, and suggest that Augmented Reality has some potential to be effective in aiding the learning of 3D concepts". The benefit was also identified by Martín-Gutíerrez et al. [16, p. 5]: "the training of spatial ability based on Graphic Engineering contents and AR technology improves spatial abilities for those who perform them and consequently lower the numbers of students who drop out of the subject". This benefit is also mentioned by Martín-Gutíerrez et al. [17] and Chen and Wang [27].

Improved Memory. Improved Memory refers to the retention of knowledge acquired during the use of an AR application. Hou et al. [23, p. 450] state that "trainees with AR training could remember or recollect more assembly clues that were memorized in the former training task than those trained in the manual". Furthermore, this benefit is not only about memory itself but also refers to the vividness of the memory. As Chang et al. [25, p. 193] point out, "[the AR application] facilitates the development of art appreciation […], supporting the coupling between the visitors, the guide system, and the artwork (Klopfer & Squire, 2008) by using AR technology, and helping visitors keep their memories of the artwork vivid". Macchiarella et al. [34, p. 4] conclude that AR "lead[s] to an increased ability to retain long term memories".

4.6 Reduced Costs

Leblanc et al. [35] and Martín-Gutíerrez et al. [16] report Reduced Costs in AR-scenarios compared to traditional learning in the long term. Chen and Tsai [28] in particular highlight the low cost in executing manpower and moderate costs for designing and renewing the courses. Andujar et al. [36] agree on this benefit, especially for virtual laboratories. They add that AR applications not only reduce direct costs, such as needed materials, but also time for preparing classes. While AR technology is accompanied with high acquisition cost, this investment is most likely to pay off in the long term. Leblanc et al. [35] conclude that, while one time acquisition cost were high, the cost per class could be lowered by 93.34%, reducing overall costs.

5 Mapping of the Benefits to the Five Directions

Table 2 maps the benefits to the Five Directions. This mapping is discussed below.

Discovery-based Learning. We found eight articles which present learning concepts that were discovery-based. Those articles had the most mentions of state-of-mind benefits, especially Increased Motivation. Also, an Improved Learning Curve was mentioned. Nine out of 14 benefits were reported for Discovery-based Learning applications, which is the most diverse pool of benefits in our literature review. Reduced Costs were reported in one article for Discovery-based Learning applications.

Objects Modeling. We identified five articles dealing with an Objects Modeling approach. Similar to Discovery-based Learning applications, Objects Modeling resulted in an Increased Motivation and Increased Satisfaction. We found four articles mentioning Increased Motivation in an Objects Modeling context. Also, an Improved Learning Curve was observed. It is noticeable that, although Objects Modeling itself is highly interactive, we did not identify references of Increased Interactivity. Also, we did not find reports of Increased Creativity linked to Objects Modeling, but spatial abilities were reported to be developed better. Objects Modeling applications are reported to have reduced costs in comparison to non-AR learning tools.

Table 2. Mapping of Benefits to Directions
(25 articles, 6 benefit groups, 14 different benefits and 5 directions)

		Discovery-based Learning	**Objects Modeling**	**AR Books**	**Skills Training**	**AR Gaming**	**Total**
State of Mind	*Motivation*	7	4	2	1	1	15
	Attention	2	0	1	0	0	3
	Concentration	2	0	0	0	1	3
	Satisfaction	1	2	0	1	1	5
Teaching Concepts	*Student-centered Learning*	2	0	1	0	0	3
	Collaborative Learning	1	2	0	0	0	3
Presentation	*Details*	0	0	0	1	0	1
	Accessibility Information	0	0	0	1	1	2
	Interactivity	1	0	1	0	0	2
Learning Type	*Learning Curve*	6	4	1	6	1	18
	Creativity	2	0	1	0	0	3
Content Understanding	*Spatial Abilities*	0	2	1	1	0	4
	Memory	1	0	0	2	0	3
Reduced Costs	*Reduced Costs*	0	1	0	1	0	2

AR Books. Two articles were based on AR Books applications. AR Books applications were the least found direction. Six out of 14 benefits were reported in context of AR Books. No Reduced Costs were reported for AR Books applications.

Skills Training. Seven articles presented a Skills Training AR application and seven out of 14 unique benefits were mentioned in in this regard. Skills Training applications have most mentions of Content Understanding, especially in Improved Memory. It is also noteworthy that Skills Training applications have the same count of mentions for Improved Learning Curve as Discovery-based Learning applications. Both have the highest count for Improved Learning Curve. It was reported that Skills Training applications reduced costs in comparison to traditional learning tools.

AR Gaming. AR Gaming was shown in three articles. AR Gaming has most benefits in the State of Mind group. An Improved Learning Curve and better accessible information were reported. Content Understanding and Teaching Concepts were not explicitly improved in the reviewed cases. Reduced Costs were reported in one article.

6 Discussion

Compared to the previous study by Radu [5], our study has some similarities as well as some distinctions. Radu [5] mentions Spatial Abilities, Long Term Memory, Collaboration, and Motivation as AR benefits, which are supported by our results. However, we aggregate Content Understanding, Language Association, and Physical Task Performance into Improved Learning Curve. Depending on the direction of the application, we are able to disaggregate our aggregated benefit Improved Learning Curve into a more detailed benefit, that is, Skills Training application with an Improved Learning Curve conforms to Physical Task Performance. We defined Improved Development of Spatial Abilities as another benefit and even in another group, as some applications lead to a new level of spatial abilities, which might not have been achieved without AR or is at least extraordinary improvements in spatial abilities. Martín-Gutíerrez et al. [17, p. 4] states that "[...] the students have a probability of over 95% of improving their levels of spatial ability when performing the proposed training. Besides this, results show there is no improvement in control group levels", which indicates that spatial abilities were improved far more than usual. In contrast to Radu [5], we divided Attention into two benefits, that is, Increased Concentration and Increased Attention. While Radu [5] states that AR applications might fail to improve student attention or lead to an unintended focus on the technology itself rather than the topic, we found articles that state the opposite. Kamarainen et al. [14, p. 554] highlights that "[t]he teachers stated that they began this project with skepticism about whether the technology would overwhelm the experience, holding the students' attention at the expense of their noticing the real environment. However, teachers and investigators found the opposite to be true. Students were captivated when a squirrel dropped a seed from a tree near the path and nearly hit a classmate; they called out excitedly when they observed a frog near the shore". We thus believe the drawback mentioned by Radu [5] to be related to system design. Furthermore, our differentiation between attention and concentration is based on the findings by Kamarainen et al. [14, p. 554]. Attention relates to an increased awareness of the situation and a focus on the broader environment only, while concentration refers to an increased awareness of the topic or subject and a high level of cognitive activity. In addition to Radu [5], we identified the following benefits: Reduced Costs, Student-centered Learning, Increased Creativity as well as all presentation-related benefits like Increased Details, Increased Information Accessibility, and Increased Interactivity. We found Increased Creativity to be a surprising benefit of AR applications. We rather expected AR applications to display prescribed information and interact in predefined ways. Our findings conversely show that AR applications are able to support creative, non-linear learning. This finding also stresses that AR is a very flexible tool which can be used in many educational environments and settings and for very different purposes if it is applied thoroughly. Hannafin and Land [37, p. 197] state that although "[s]tudent-centered learning environments, with or without technology, will not be the system of choice for all types of learning", "[Student-centered Learning environments] represent alternative approaches for fundamentally different learning goals" [37, p. 197]. Thus, "[i]t is important to recognize, however, that viable alternatives to direct instruction methods exist, alternatives that reflect different assumptions and draw upon different research and theory bases than do traditional approaches". These statements make us believe that Student-centered Learning, especially with AR as a tool, may be an important new movement for education. Discovery-based Learning seems to be a very promising AR direction. As outlined in Section 5, this direction includes benefits ranging from Increased Motivation and Improved Learning Curve to Reduced Costs and Increased Student-centered Learning. Supporting a Discovery-based Learning-approach, the student is the center of the learning process and the learning process is adjusted to the student's needs and preferences. This seems a promising way of learning in the future. Our study is limited by a number of factors. First, the identified empirical studies are only informal investigations with a low number of participants. The significance of the ascertained benefits of AR applications may be unclear in these cases. However, these studies are based on experiments and thus are able to reveal causal relations. For some of the regarded directions, we did not find sufficient articles in order to make a point about the diversity of benefits compared to other directions. However, AR is one of the most emerging technologies in education and the fact that 15 out of 25 articles were published in 2012 or later shows that these limitations can be overcome in the future when further empirical evaluations of AR applications in educational environments are published. Another factor that limits our study is the inter-coder reliability of 0.64 regarding the classification of articles to a certain direction of AR. We believe that this rather low value can be explained by the circumstance that some articles cannot be precisely classified to a single direction (e.g., a Discovery-based Learning application which uses game elements). In addition, the definitions by Yuen et al. [1] leave some room for interpretation, which we attempted to reduce before we conducted our systematic literature review in order to ensure a common understanding. However, since research on AR benefits can be considered to be at an early stage, reliabilities of .70 or higher suffice [38]. Our value is thus only marginally below the recommended threshold. To keep the focus on the primary classification of every article, we decided to allow only single classifications and accepted a lower inter-coder reliability. Another aspect we left out are 'special learners': while handicapped people have (sometimes) special requirements, we focused on more general aspects of AR in educational environments.

7 Conclusion

AR is eligible to be used in educational environments and we identified many applications successfully applying AR to improve learning: language education, training of mechanical skills, and spatial abilities training. Nevertheless, AR should not be considered a magic bullet in educational environments. Each AR application is in its own way unique and therefore the identified benefits may not apply in each context. Each application has to be implemented thoroughly to prevent drawbacks in user interaction or system failures in order to profit from benefits. Special user groups (e.g., handicapped people) can benefit in different as well as additional ways due to their requirements to learning methods and the characteristics of AR. The exploration of these benefits could be an objective for future research in the field of AR applications in educational environments. We identified 14 different benefits of AR in our source literature of which two (Improved Learning Curve and Increased Motivation) account for more than 20% of all benefits mentioned. Other benefits with much lower representation could be in the focus of future works assessing AR applications in educational environments. Future research should also focus on each of the Five Directions.

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