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Selected Issues II
Major Information Systems

Benefits of Augmented Reality in Educational Environments

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1. Introduction

1.1 Problem Statement

Bridging the gap between virtual and real worlds, Augmented Reality (AR) provides new possibilities of teaching and learning which have been increasingly recognized by educational reaserchers.[1] Although AR is one of the most emerging technologies in education in these days,[2] the unique value of AR learning environments remains unclear.[3] In addition, there are different types of AR applications in educational environments which may differ regarding their benefits towards educational outcomes.[4] This leads to the problem that teachers and professors may be not aware of potential benefits of AR applications in comparison to conventional learning tools.

This work considers two main research questions: 1.Which benefits are provided by an AR application in comparison to conventional learning tools? 2. How do those benefits differ regarding the different types of AR applications in educational environments?

Although recent studies have investigated the use of AR in educational environments[5][6] and a first approach to consolidate AR Benefits in educational environments has been made,[7] more evidence on the educational values of AR is needed 1.1. Unfortunately, we were not able to replicate the approach by Radu(2014) in order to search for additional benefits because of missing information towards the applied methodology. In addition this approach does not consider the different types of AR applications in educational environments.

An overview of the benefits of AR in educational environments regarding the different types of AR applications would help teachers and professors to decide whether the implementation of AR is reasonable in certain educational scenarios.

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1 cf. Wu et al. (2013), p. 41.

2 Johnson et al. (2010), cf.

3 cf. Wu et al. (2013), p. 48.

4 cf. Yuen et al. (2011), pp. 127-130.

5 Wu et al. (2013).

6 Lee (2012).

7 Radu (2014), cf.

1.2 Objectives

1.3 Structure

2. Augmented Reality in Educational Environments

2.1 Definition of "Augmented Reality"

2.2 Five Directions of Augmented Reality in Educational Environments

3. Systematic Literature Review

We applied a two-step research approach, whereby we first conducted a systematic literature review to identify relevant publications before analysing the identified publications for the coding of benefits and directions. After coding, we grouped all found benefits. This process is illustrated in Fig. 3-1 for data collection and in Fig. 3-2 for data analysis.

3.1 Data Collection

For the identification of papers addressing Augmented Reality in educational environments, we applied a systematic online literature database search. We included databases which were specialised on more information systems centered papers, namely Institute of Electrical and Electronic Engineers (IEEE) Xplore Digital Library, ProQuest (ABI / INFORM), Association for Information Systems Electronic Library (AISel) and Association for Computing Machinery (ACM) Digital Library, as well as more general databases, namely EBSCO Host and ScienceDirect.
To find relevant papers, we searched within all databases with on the following attributes: title, abstract and author supplied keywords. Within these keywords we had three mandatory groups of keywords. Every article had to include the keyword "Augmented Reality ". Additionally, every article needed to have at least one synonym for education and benefits. Namely we searched for "Educat*", "Learn*", "Teach*", "College" or "School" as synonyms for education and "Benefi*", "Advan*", "Improv*", "Enhanc*", "Driver*" or "Value*" as synonyms for benefits. To deal with the limitations of some databases, we had to split our query and conduct multiple queries on the database and merge them together by hand.
This database query resulted in a total of 523 articles. Those results were checked against our include- and exclude-criteria, which are listed in Tab. 3-1. We limited the results to empirical works, because we wanted to gain insights into benefits applied systems and benefits in real-world scenarios. Also, we focused only on positive effects to reduce the amount of data to process. Other aspects we excluded explicitly are non-human learning scenarios like machine learning and learning contexts with special requirements like students with disabilities. Both aspects were left out of our research because they require special attention.

This process of data collection was performed by ourselves and each article was read by two of the authors. After merging our results, a total of 25 articles remained.

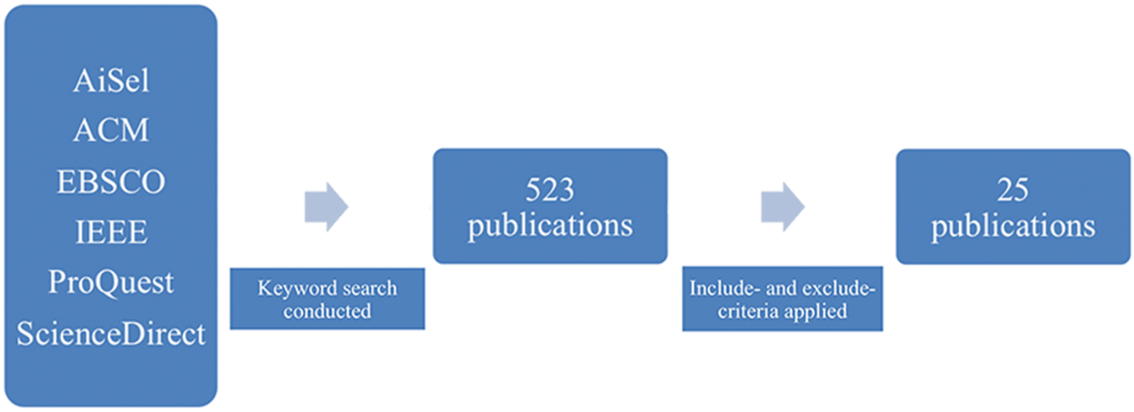

Fig. 3-1: Research Approach: Data Gathering

Include Criteria	**Exclude Criteria**
Empirical works	Theoretical works, grey literature, dissertations
A teaching problem is solved with the help of Augmented Reality or a teaching concept is improved by Augmented Reality	Untried or untested technologies, concepts without empirical evidence
Lists positive effects of Augmented Reality applications in comparison to conventional learning tools	No control-group or control-scenario provided, no comparison to conventional learning tools
Human learning	Machine learning
English language	Other language
Peer-reviewed	Not peer-reviewed
Students without disabilities or special requirements	Students with disabilities or special requirements

Tab. 3-1: Include- and Exclude-Criteria

3.2 Data Analysis

During data analysis we clustered all found benefits into major groups and matched all found benefits to the directions of the articles in which they were mentioned. We will go into details regarding the benefits found and the clustering of them in chapter 4.1 and the mapping process will be highlighted in chapter 4.2.

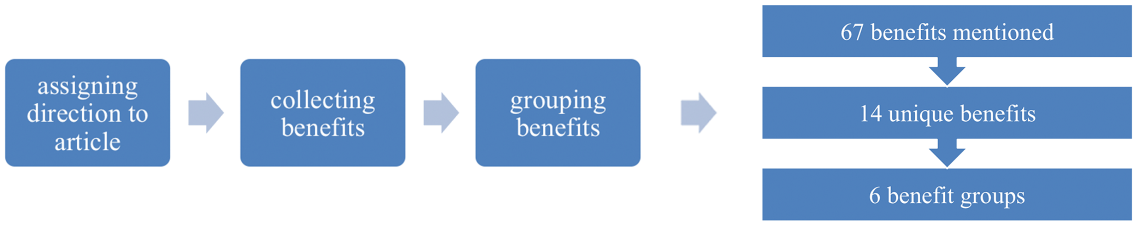

Fig. 3-2: Research Approach: Data Analysis

Because of our orientation towards the five directions, we assigned preliminary directions to all articles during data collection but revised our assignment in case of differences between the first and second coder. To measure our precision regarding the coding of the articles into directions, we utilised the inter-coder reliability score, proposed by Miles and Huberman.[8] This score is calculated by dividing the number of agreements by the total number of agreements and disagreements. Our inter-coder reliability score is 0.64. We will interpret and discuss this score in chapter 5.

During assignment of directions we also collected all mentioned benefits and generalised similar benefits into a single one. Afterwards, those benefits were grouped into broader topic-related benefits. The process we applied is based on the process proposed by Jankowicz.[9] The process proposed by Jankowicz helps by formalising the process of clustering.

A total of 67 benefits were mentioned, containing 14 unique benefits, which were clustered into six clusters. In the next chapter, we will introduce all found benefits and their major groups.

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8 cf. Miles, Huberman (1994), p. 46.

9 cf. Jankowicz (2004), p. 149.

4. Benefits of Augmented Reality in Educational Environments

4.1 Benefit Categorization

4.1.1 State of Mind

Increased Motivation

Increased Attention

Increased Concentration

Increased Satisfaction

4.1.2 Teaching Concepts

Increased Student Centered Learning

Improved Collaborative Learning

4.1.3 Presentation

Increased Details

Increased Information Accessibility

Increased Interactivity

4.1.4 Learning Type

Improved Learning Curve

Increased Creativity

4.1.5 Content Understanding

Improved Development of Spacial Abilities

Improved Memory

4.1.6 Reduced Cost

4.2 Mapping of the Benefits to the „Five Directions“

Following, we will present the mapping of the found benefits to the five directions. In **??** the mapping results are listed in detail.

TODO: Describe pattern and procedure? Maybe more Detailed in 3.2?

4.2.1 Discovery-based Learning

We found eight articles (32.00% of all articles in our result set) whose presented learning concepts were Discovery-based. Those articles had the most mentions of state of mind benefits, especially increased motivation. 47% of all increased motivation benefits were related to a Discovery-based Augmented Reality application. Also, an improved learning curve was mentioned. About one-third of all improved learning curves were observed in Discovery-based Learning environments. Nine out of 14 benefits were reported for Discovery-based Learning applications (about 64.29%), which is the most diverse pool of benefits we found during our literature review. No reduced costs were reported for Discovery-based Learning applications.

4.2.2 Objects Modelling

In our result set of 25 articles, we found five articles (20.00% of all articles reviewed), which dealt with an Objects Modelling approach for the presented Augmented Reality application. Similar to Discovery-based Learning applications, Objects Modelling resulted in an increased motivation and satisfaction. We found about 26.67% of all mentions of increased motivation in an Objects Modelling context. Also, an improved learning curve was observed. About 22.22% of all mentions of an improved learning curve were coherence with an Objects Modelling application. It is noticeable, that although Objects Modelling itself is highly interactive, we did not find any references of an increased interactivity in classes which used Augmented Reality than in classes which did not. None of the Objects Modelling applications mention presentation-linked benefits. Also, we found no reports of increased creativity linked to Objects Modelling , but spatial abilities were reported to be developed better. Five different benefits were found in Objects Modelling applications, which is about 35.71% of all reported unique benefits. Besides Skills Training applications, Objects Modelling applications were the only ones which were reported to have reduced costs in comparison to non-Augmented Reality learning tools.

4.2.3 AR Books

Two articles (which makes a total of 8.00%) were found which were based on an AR Books application. AR Books applications were the least found in the articles. AR Books applications are also connected to an increase in motivation, but not as much as Discovery-based Learning or Objects Modelling. AR Books seem to provide balanced benefits. Six of 14 benefits were reported in context of AR Books which makes about 42.86%. No reduced costs were reported for AR Books applications .

4.2.4 Skills Training

We found seven articles (28.00% of all articles) which presented a Skills Training Augmented Reality application. 50.00% (seven out of 14) of all unique benefits were also mentioned in Skills Training applications. Skills Training applications have the most mentions of content understanding, especially in improved memory. It is furthermore worth noticing, that Skills Training applications have the same count of mentions for improved learning curves as Discovery-based Learning applications. Both have the highest count for improved learning curves. Like Objects Modelling applications, it was reported, that Skills Training applications reduced the costs in comparison to traditional learning tools.

4.2.5 AR Gaming

AR Gaming was presented in three articles of our result set which accounts for 12.00%. AR Gaming has most benefits in the state of mind group. An improved learning curve as well as better accessible information were reported. Content understanding and teaching concepts, such as collaborative learning, were not explicitly improved in the reviewed cases. No reduced costs were reported for AR Gaming applications.

		Discovery-based Learning	**Objects Modelling**	**AR Books**	**Skills Training**	**AR Gaming**	Sums
State of Mind	Increased Motivation	7	4	2	1	1	15
	Increased Attention	2	0	1	0	0	3
	Increased Concentration	2	0	0	0	1	3
	Increased Satisfaction	1	2	0	1	1	5
	Sums	12	6	3	2	3	
Teaching Concepts	Student Centered Learning	2	0	1	0	0	3
	Improved Collective Learning	1	2	0	0	0	3
	Sums	3	2	1	0	0	
Presentation	Increased Details	0	0	0	1	0	1
	Easy Accessible Information	0	0	0	1	1	2
	Interactivity	1	0	1	0	0	2
	Sums	1	0	1	2	1	
Learning Types	Improved Learning Curve	6	4	1	6	1	18
	Increased Creativity	2	0	1	0	0	3
	Sums	8	4	2	6	1	
Reduced Costs	Reduced Costs	0	1	0	1	0	2
Content Understanding	Development of Spatial Abilities	0	2	1	1	0	4
	Improved Memory	1	0	0	2	0	3
	Sums	1	2	1	3	0	

Tab. 4-1: Mapping of Benefits and Directions

5. Discussion

6. Conclusion

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