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Research Article

Augmented Reality and Education: Digital Transformation in Primary School

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Abstract

Technology is driving the aspects of our professional and personal applications through the use of devices and computers. It has impacted the way businesses operate and started changing the way education system works. During the pandemic technology has supported education online as well as disrupted the traditional way of teaching and learning. Education technology companies have provided multiple ways to deliver education. One of the education technologies that is driving digital transformation is augmented reality. Augmented Reality has been gaining popularity at different levels of education and used to explain information visually and in a 3D format. The strongest side of augmented reality is the visual representation of curricula and this can support different learning styles and pedagogical approaches. This study provides a literature overview on how augmented reality has created a digital transformation in the primary education sector through observations and analysist of existing peer to peer reviewed publications as well as provides further research suggestions.

Introduction

In today's modern world schools are obliged to have digital tools for teaching and learning, they force to innovate and break traditional pedagogical methods to accommodate teaching and learning for the development of 21st century skills and learning demands of digital natives [1]. The education technology market rise is influenced by the Industrial Revolution 4.0 and growing technological demands and innovation [2]. According to market insider [3], the global education technology market is projected to reach $342B by 2025. There are several studies, for example, by Bulman & Fairlie [4], Holland & Holland [5], and Collins & Halverson [6] related to the integration of innovative technologies in education and current challenges the educational industry comes across during the digitalization age. With the development of education technology and modern technological tools like mobile devices and touch boards, students and teachers have access to interactive learning environments that can provide virtual information access, visualization of subjects and support combined evidence of physical and virtual worlds [7]. As a result of educational technology advancement as well as online teaching needs, augmented reality is gaining momentum and attention [8]. Augmented reality solutions and applications for education are available on mobile devices like tables and mobile phones as the most popular means of interacting with technology and having access to virtual content [9]. There are use cases for the virtual environments reproduced in a web-based interface through cloud servers and activity links embedded for the convenience of users to access solutions on a computer or laptop [10].

Augmented Reality has shown sufficient results in different areas of education process including improved students' motivation and information retention [11,12] increased interest and engagement in studies [13,14] improved test scores compared to non-technology subject area teaching [15,16]. Nevertheless, there is lack of literature reviews focused on primary education sector as the existing publications represent mix of primary, secondary and high education researches. There is a gap that needs attention specifically on primary education and how augmented reality has changed the approaches of teaching and learning using the new technology. With that in mind, this literature review article aims to investigate the digital transformation in primary education with the focus on augmented reality and the use cases of adopting this technology. With multiple cases of augmented reality technology applications, it is important to understand the most popular applications and subject areas as well as the efficiency and potential of this technology adoption.

Research Questions

Keeping in mind that there are many studies and publications that report the advantages and challenges of introducing augmented reality technology at primary school level, it is interesting to focus on how this technology has transformed teaching methods and has influenced the learning outcomes. The suggested context suggested the following research questions:

a)   How has augmented reality digitally transformed teaching and learning at primary school level?
b)   What is the main subject/curricula areas where augmented reality technology is used?
c)   What are the main outcomes of digital transformation driven by augmented reality?

Method

For this literature review the guidelines proposed by Kitchenham [17] were used to perform the below steps:

a)   **Planning:** Selection of publications, creating definition for studies/preliminary categories of analysis to be included or excluded, definition of analysis categories.
b)   **Conducting review:** Study of selected publications and research papers, data extraction and synthesis.
c)   **Reporting:** Data analysis of finding, conclusions and results.

During the planning stage it was important to identify the criteria according to which the literature search will be conducted. The main criteria set were the following:

a) Studies that describe augmented reality technology adoption in primary education
b) Studies that describe augmented reality applications that cover specific subjects in primary education
c) Studies that describe outcomes and impact on using augmented reality in primary education.

There were exclusion criteria identified to narrow down the papers that focus on the research questions identified in this literature review:

i.   Studies that cover Virtual Reality and mixed reality
ii. Publications that do not mention Augmented Reality and primary education
iii. Studies about Augmented Reality not focusing on primary education.

The selection of research papers for this study has been conducted using IEEE xplore, Springer and Web of Science libraries. The search was performed using the following key phrases "Augmented Reality in primary school", "Augmented Reality in primary education", "Impact of Augmented Reality in primary education", "Augmented Reality and pedagogy in primary education", "Augmented Reality teaching and learning in primary education", "Augmented Reality digital transformation in primary education". (Table 1) provides a detailed overview of the number of articles, research studies and publications that have been found for the conducting of this literature review.

Table 1: Query strings and number of studies.

Digital Library	Search String/S Used	Studies Found		Studies Selected
IEEE xplore	"Augmented Reality in primary school"	Journals 9		7
		Conferences 19		
	"Augmented Reality in primary education"	Journals 6		9
		Conferences 16		
	"Impact of Augmented Reality in primary education"	Journals 74		11
		Conferences 7		
	"Augmented Reality and pedagogy in primary education"	Conferences 2		0
	"Augmented Reality teaching and learning in primary education"	Journals 2		12
		Conferences 8		
	"Augmented Reality digital transformation in primary education"	Journals 12		5
Springer	"Augmented Reality in primary school"	Journals 29		10
		Conferences 8		
	"Augmented Reality in primary education"	Journals 21		10
		Conferences 17		
	"Impact of Augmented Reality in primary education"	Journals 64		18
		Conferences 7		
	"Augmented Reality and pedagogy in primary education"	Journals 12		7
		Conferences 8		
	"Augmented Reality teaching and learning in primary education"	Journals 37		7
		Conferences 32		
	"Augmented Reality digital transformation in primary education"	Journals 33		14
		Conferences 6		

Web of Science	"Augmented Reality in primary school"	Journals 21	3
	"Augmented Reality in primary education"	Journals 10	4
	"Impact of Augmented Reality in primary education"	Journals 20	5
	"Augmented Reality and pedagogy in primary education"	Journals 12	4
	"Augmented Reality teaching and learning in primary education"	Journals 17	9
	"Augmented Reality digital transformation in primary education"	Journals 18	12

Out of pre-selected 833 studies from the overall search there have been 93 selected for this literature overview and analysis as pictured in (Figure 1).
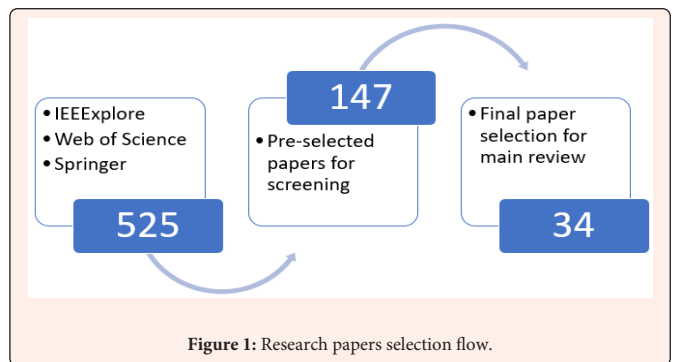

Figure 1: Research papers selection flow.

The contents of pre-selected studies were analysed and the observations were grouped according to the research questions focusing on how Augmented Reality transformed primary education, for which subject areas the technology is mainly used and what impact was observed by the researchers. The method was applied during the systematization and analysis of the papers that produced the conclusion and study.

Results

This section of the literature review study provides the findings overview connected to the research questions. After manual research in three digital libraries, removing duplications and narrowing the studies to the core research questions stated 34 papers have been selected. Out of 34 selected papers 7 are systematic literature review publications.

Pre-selected literature review findings

The below systematic literature reviews have been selected and used for this study. The detailed information is in (Table 2).

Table 2: Systematic literature reviews on augmented reality in primary education.

Research Study, Year	Objective of the Research	Number of Studies Reviewed	Observations & Findings
Diegmann [18]	Benefits of AR in educational environments and how they differ depending on AR application	25	AR has multiple applications in education: learning: language education, training of mechanical skills, and spatial abilities training however is not a magical solution for everything. Benefits depend on learning methods and the characteristics of AR. Identified the following benefits of AR: improved learning curve and increased motivation.

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Liono [19]	How visual learning can help students to comprehend information better	32	Augmented Reality appears to be an effective tool for learning however students cannot grasp the generalization of concepts just by using AR. Generally, AR motivates students to study and improves their attention span, gives opportunity for students to experience things that they may not or impossible to experience. AR technology should be easy for teachers to introduce in their lessons and help to explain certain subjects.
Herpich [20]	Application of Augmented Reality in education	57	AR has positive implications on teaching and that mobile augmented reality has shown an exponential growth with favourable signs to contribute to education.
Bacca Acosta [21]	Augmented Reality trends in education	32	Study covers different types and levels of education and provides a general overview of an increasing trend for AR use in teaching and learning with a positive impact.
Avila-Garzon [22]	Overview of 25 (1995-2020) years of research on the application of Augmented Reality	3475	The current emerging and trending research topics in AR in education are special educational needs, Industry 4.0, storytelling, 3D printing, mobile applications, and higher education. There is an increasing interest in technology and its application.
Samad [23]	Advantages and challenges associated with Augmented Reality in education	40	Augmented Reality use in education is increasing as technology gains more attention and more education technology providers suggest new solutions for multiple areas and levels of education. The challenges are mainly connected to the equipment issues at schools and AR solutions selection.
Garzón [24]	Meta-analysis of Augmented Reality in educational settings	61	AR in education has been steadily increasing since 2010. The development and use of AR technologies are increasing, worldwide. AR technology may reach even more maturity and application across different industries including education sector.

As it can be noticed, augmented reality is a technology that is gaining it's maturity across different industries as well as finds it application in visualizing concepts and information [22,24]. There has been a positive impact observed on how augmented reality supported different learning styles and teaching learning needs by increasing motivation and interest in the learning process, supporting students' information retention and creating the environment for motivation [19-21] Augmented Reality as a tool has found different applications in subject areas from language learning, to STEM subjects and social studies [18].

Findings on how augmented reality digitally transformed teaching and learning at primary school level

Technology is changing the landscape of education on a daily basis and the teachers of today are not the same tomorrow with their approaches to education and tools they use [25]. Bower [26] mention that augmented reality is transforming the education by making the information available for students at the time they need it and at the pace they require. This makes the place for technology not only at school level but also in day-to-day life. Applications for Augmented Reality are growing and provide marker-based and marker-less solutions, location-based content aggregators, images triggering and interactive modelling, creating AR environments and embedding media in AR solutions, creating own games using technology and others [26]. Wei [27] observed that educators are not rushing to use new technologies however introduction of augmented reality at schools is growing because it creates exciting environments and supports learning progress. Educators are accepting augmented reality as an easy-to-use tool to do visual demonstration of information they teach simpler and easier however sometimes there is a perception that teachers need to be technology-savvy to use augmented reality. Oleksiuk & Oleksiuk [28] in their research claim that thanks to the fact that augmented reality solutions are available to use on laptops, mobiles devices and desktops alike creates a wide range of opportunities for primary schools to adapt this technology and enrich educational experiences for both students and teachers. It brings interactivity of multimedia environments that deliver essential information and represents this information in different forms and contexts for learners [29].

According to Diegman [18] the transformation of teaching in primary school with augmented reality forms multiple educational environments that include discovery-based learning when real world objects are augmented inside classroom or museum settings; objects modelling for physical properties investigation and interactions between augmented objects from real life; Augmented Reality books with 3D animations on the pages that make information come to life; skills training by using digital technology; Augmented Reality gaming with interactive testing elements and games that teachers can use as new powerful ways to attract students' attention to studying. Augmented Reality helps to enable real time learning experiences visualised and interactive, embedded into real world scenarios and supportive for multiple range of disciplines [25]. Some applications with augmented reality have pre-packed solutions which can lead to interactivity however lower thinking and creativity process. For better learning outcomes it is advised to use learning by design applications where students can use their creativity and team work for making own experiences guided by teacher [26]. Suselo [30] describe Augmented Reality as a convenient and easy to use tool to augment information in 3D objects which leads to improvement of understanding of the material presented by teacher and helps learners to use visualization of information transformation. This is a novel way of helping students to develop critical thinking and imagination during learning process. This transforms the way of teaching especially when students have the possibility to create augmented experiences right in the classroom settings. To summarize, the transformation of education at the level of digital tools introduction has started and more to come. Augmented Reality technology is being used and adopted with slight challenges of technical equipment to use the software and sometimes lack of training for teachers to feel conformable in adopting technology as well as introducing it in their classroom settings. The benefits of digital transformation at primary education driven by augmented reality there is a good chance of having more interest and engagement from the side of students in teaching and learning process.

Overview of the main subject/curricula areas where augmented reality technology is used

Applications for Augmented Reality are growing and provide marker-based and marker-less solutions, location-based content aggregators, images triggering and interactive modelling, creating AR environments and embedding media in AR solutions, creating own games using technology and others [26]. As the capabilities are growing, technology enables teachers to use its applications in their classroom settings more often, mention [26]. The researchers discovered that Augmented Reality found its application in literature studies and supports different pedagogical approaches that are not limited to constructivist learning, situated learning, games-based and enquiry-based learning. Some solutions with Augmented Reality support learning by doing or learning by designing in different subject areas. Thus, Bower [26] provide an overview of several augmented reality applications where students have created their own artworks for subjects like

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history, science and arts. Augmented Reality is extensively used in primary education for teaching STEM subjects (Geometry, Geography, Science and others) claim Yegorina [31] in their research. The use of augmented reality in this research was focused on the multi-user aspect where the interactivity between teams of students for learning with technology was taken into consideration. Although, this area of use of augmented reality in primary education is relatively new, there are multiple applications in the research papers mention. They cover marker-based, marker-less and location-based augmented reality solutions for the variety of subjects range in primary school.

Combining real and augmented world is now possible in computer science education thanks to augmented reality at a beginner level [28]. This creates new opportunities for both teachers and students to try 3D visual programming skills that involve use of several applications available mention Oleksiuk & Oleksiuk [28]. It does however require extra preparation form a teacher to run a computer science class that involves Augmented Reality visual programming. Physics course as a par of science discipline made it possible to avoid issues when conducting experiments because teachers can deliver experiment contents in a visual and hazard-free format as well as students can repeat the same experiment multiple times [29]. Sagan [32] conducted research at primary school level using augmented reality from the point of interactivity and its application on art and design, geography, literature, science, creativeness, history, mathematics. The use of technology at primary school age has shown positive results with some challenges as being technically savvy from teacher's side that can influence the efficiency of technology use. Kerawalla [33] conducted a study on science education in primary school with the support of Augmented Reality: understanding of planet earth and sun by interacting with the application where students could rotate objects and understood relationship between sunlight and night and day. Augmented Reality proved its efficiency in other domains of science, for example, studies in molecular structure learning. Researchers claim that success of the study and a great potential of augmented reality for education. Game-based team work with the use of the software showed more engagement and motivation in the studies; interactivity elements supported motivation in exploring more about subjects of studies. To conclude, the mention of multiple subject areas already covered by Augmented Reality application provides confidence in further development in the field. Augmented Reality is a 3D visualization technology and it is important to keep in mind that not all school disciplines require material visualization. The application of this technology at primary school level helps to engage students in the creative process of interacting and learning with digital tools.

Findings on the main outcomes of digital transformation driven by Augmented Reality

Augmented Reality is getting awareness in education among teachers, students and parents as well as of technology's potential to improve learning experience because of the diversity of applications coming up each year covering multiple disciplines at school [34]. According to Yuliono & Rintayati [25], Augmented Reality supported changes in educational settings when used at school. The researchers have observed three categories that were influenced by this technology: learner outcomes, pedagogical contributions and interactions. In the category of learner outcomes there have been enhancement, motivation and positive attitude towards learning observed. Augmented Reality helped students to improve their skills and impacted their motivation in learning. From the side of pedagogical perspective, there was more enjoyment in the learning process together with increased engagement in the learning process noticed. Education process shifter from teacher-centred to student-centred where technology helped students to acquire information independently, gain new experiences and make the whole process of education more attractive. The levels of interaction with materials increased because students were able to drive their learning outcomes through context-related learning. Diegmann [18] noticed increased motivation on the side of students who dealt with new technology compared to non-augmented reality methods of delivering the same information. Students appeared to be more eager to join each new lesson where the technology is used. Additionally, there was increased attention and concentration during lessons when students interacted with technology as well as higher satisfaction regarding both educational process and its outcomes. The pedagogical outcomes have positive notion as well on the side of improved student-centred learning and collaborative experiences during lessons. Based on the research outcomes by Kerawalla [33], augmented reality software should have flexibility and support individual learning needs because this can help teachers to adapt it easier. There is a need to deliver curriculum related material and education technology providers should have this in mind when delivering software contents. Students needs flexibility and a good mix of interactivity inside the applications because this can help to keep the engagement and motivation and the use of the software will not be boring.

Interesting enough that Hovarth [35] highlights improved learning efficiency (30% in students' teamwork, 50% increase information understanding and retention, 50% critical thinking improvements) when augmented reality technology was used. The results of the experiment conducted by Sagan [32] in primary school at variety of subject areas show increased interest and motivation (33,3%) in educational process and more engagement (83,4%) from the side of students when they interacted with animation in 3D. The cognitive interest increased up to 72%. Based on research conducted by Nurbekova & Baigusheva [36], students (88%) and teachers (86%) trust that use of augmented reality solutions for teaching and learning increases efficiency of the process however the research results shown that understanding of the learning material by students with augmented reality increases by 96% and motivation or finding the learning engaging by 98%. Students noticed that when they learn theoretical material with augmented reality it helps to remember it better by 85%. Researchers claim that the main didactical principles of "visibility, the connection of theory with practice, consciousness and activity, accessibility, strength, science, system and consistency" are feasible to achieve with augmented reality technology. Based on the overview, it is clear that augmented reality proves to be an efficient tool for both target groups: teachers and students. The increased motivation and information retention, engagement in educational process and higher achievements of students showcase the benefits that technology provides.

Discussion

The objective to conduct this literature review was to show case the importance of the augmented reality applications in primary education covering three main areas of how the educational software created digital transformation in the sector, which subject areas are getting covered by the software and how Augmented Reality impacts teaching and learning process. The paper aimed to highlight the main areas of impact on curriculum, pedagogy and digital transformation covering the augmented reality technology as a part of digital transformation at primary school. Alongside with the subject areas and curriculum alignment it was interesting to investigate the impact of this educational technology on overall teaching processes and the outcomes that were observed from the side of teachers and how they adapt to using technology to the impact on the students and their performance, engagement and motivation in learning where augmented reality software was applied.

The study has provided the answers to three research questions:

(RQ1) How has augmented reality digitally transformed teaching and learning at primary school level?

Augmented Reality has opened new ways of introducing information through 3D visual representation compared to well-known textbooks with 2D visuals. Additionally, to the 3D visualization, augmented reality technology provides interactivity with the material presented depending on the context and scenarios in the applications. Certainly, there is some time required for teachers to get used to new tool and in some cases, they require some technical knowledge. This educational technology has opened new opportunities to engage students in teaching and learning process because it supports development of the 21ˢᵗ century skills required for the future workforce. Although this technology is still considered emerging it does show the potential for both in-class and remote learning.

(RQ2) What is the main subject/curricula areas where augmented reality technology is used?

There have been found multiple applications of the augmented reality in primary education. They cover different subject areas and open to teachers a wide range of opportunity for using it in teaching. The studies reviewed provide information that augmented reality was used in teaching geometry, geography, science, social studies, nature studies, biology, languages, history, arts, astronomy as well as computer skills learning through visual coding and developing own scenarios using 3D visualization. Some subjects have wider selection of augmented reality applications (most often geometry, astronomy, geography, nature studies) and some are less represented (chemistry, history). This gives more opportunities for education technology providers to cover the gaps. There are also different options for using technology starting from web-based applications to mobile based, form using a target image to launch augmented reality (marker-based) to location based and markerless options. The applications allow students to interact with contents, review suggested scenarios and create own augmented scenes.

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RQ3) What are the main outcomes of digital transformation driven by augmented reality?

This literature review suggests that augmented reality applications are beneficial for both students and teachers. Teachers have multiple pedagogical benefits that support teaching methods with a student-centred approach, learning by doing and developing design thinking. This technology supports teachers in developing lesson activities based on individual students' needs and help to get more engagement from the students' side. On the other side, students are more motivated and inspired to join lesson activities because of novelty approach in information introduction. The technology supports development of their curiosity and information retention in the long run which benefits better assessment results.

Conclusion

The objective of this literature review paper had focus on digital transformation in primary education driven by augmented reality technology from different angels (subject/curriculum area, teacher adoption and pedagogy, outcomes observed when using applications with augmented reality). The observations have shown a good scenario of adoption this technology in educational settings. It has created a digital transformation in primary school based on the new way of introducing learning material which appeared to be more engaging and student-focused from pedagogical perspective as well as supported teachers in creating novelty approaches for personalized learning ways. Based on the subject and application with Augmented Reality, teachers have new opportunities of delivering STEM subjects and more, engaging students in hands-on learning experiences when the possibility of creating with augmented reality was an option. Students, on the other side, are driven by interactive emerging technology because it provides the possibilities to actively learn and develops curiosity to explore the subjects' areas more. Collaborative work in teams on projects where augmented reality was one of the elements showed positive impact on the assessment and overall feedback from learners. Further introduction of augmented reality at a lager scale and support of curriculum alignment can lead to better adaption of this technology by teachers who are not technically savvy and can easily use the software. The more benefits are observed in use of Augmented Reality, the more potential adaption scenarios are possible in the future.

Research Limitations and Further Research Suggestions

This literature review paper had focus on the digital transformation aspect led by augmented reality in primary education and it has been noticed that there were challenges in adaption of this technology mentioned [19,20,31]. This paper didn't aim to observe challenges that teachers face when trying to adapt augmented reality (apart from hardware challenges). Further research area may be on the main challenges that teachers face and how to overcome these challenges by developing continuous professional development trainings and/or educational courses for both tech-savvy and non-tech-savvy educators. Furthermore, there is lack of resources that describe digital transformation of primary education with emerging technologies including Augmented Reality and can be also an objective for further research. This paper has limitations on the studies found based on the key word search preselected for this literature review and may be limited to the information retrieved from the three search sources.

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