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PAPER

Assessing the Teachers' Readiness for Integrating Augmented Reality in K-12 Education: A Comparative Analysis

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ABSTRACT

The integration of augmented reality (AR) into educational environments will depend on its perceived effectiveness in enhancing teaching practices and the attitudes toward the use of this technology. Therefore, the main objective is to investigate the teachers' attitude and motivation to adopt AR in educational settings, which also looks at a cross-cultural context. Furthermore, this research reveals different aspects that have an impact on teachers' attitudes toward adopting AR in the teaching process. To investigate this, we conducted a study with 87 K-12 teachers belonging to two different education systems, i.e., Sweden and Palestine. The mixed-methods approach enhances the validity of the study and provides a broad understanding through numerical data, while qualitative insights offer deeper explanations of the findings. The results indicate a statistically significant difference in teachers' attitudes about AR, with a mean 3.99 for teachers coming from Palestine showing a more positive attitude towards AR-supported learning. Therefore, it is important for educational institutions and application developers to consider a range of learning and teaching methods, as well as specific needs, throughout the process of developing and incorporating AR into the curriculum.

KEYWORDS

augmented reality (AR), education, teachers, attitudes, learning, schools

1 INTRODUCTION

The recent worldwide developments, especially due to the COVID-19 pandemic, have posed immense challenges in the education sector worldwide [1]. The changed context pushed part or all educational activities across the world to be moved over distance. These new circumstances increased the level of adoption of digital technologies, mainly as it was incumbent adoption to adhere to the changed context [2]. This also brought to the front that the challenges of technology adoption in the education sector are multifaceted. Research indicates that for sustainable adoption of

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technologies into the education process, one needs to consider behavioral, emotional, and cognitive implications [3]. One of the technologies that has shown a promising potential in terms of adoption in the educational setting has been augmented reality (AR) [4]. The ability to offer the sensation of immersion while connecting across the time and space dimensions was deemed to have great potential across different education subjects.

There is a large number of research studies that are related to the possible use of AR in educational contexts [5]. Furthermore, such studies reported advantages, effectiveness, and user attitudes toward the use of AR in educational settings. According to [6], most of the reviewed literature on using AR for educational purposes was used in higher educational settings. This relates to the idea that AR is recognized as an interesting and effective tool for learning topics that cannot be easily explored in the physical world, either due to the lack of equipment or hardware or for visualizing abstract and complex ideas that are challenging to grasp through traditional methods. Accordingly, there are different examples showing such advantages of using AR in an educational context. For instance, researchers in [7, 8] showed that AR had a positive impact on students' understanding of basic concepts and skills in engineering education in higher education.

Despite the potential, the adoption of AR in the education sector has been with varying success [9]. One of the main challenges that was identified across different studies has been the lack of instructional design and pedagogical scaffolding. Furthermore, based on reports from the current study, a discrepancy exists in the acceptability and use of these tools, particularly in the context of educational technology, where only a limited number of teachers and students had made use of them.

In this line of research, in one of our previous works related to the technology adoption during the pandemic situation, we identified the need for promoting preparedness for distance teaching and learning, i.e., the need to continue the agile development of teachers' pedagogical and technical competences [10]. Especially since technology adoption was also manifested with a negative impact on teachers' motivation. Thus, understanding teachers' motivation to adopt AR in their teaching activities is crucial, especially in the post-pandemic context. To this end, we have conducted research with teachers both within an education system in a high-performing economy (Sweden) and an education system in a low-performing economy (Palestine) to gain further insight regarding behavioral, emotional, and cognitive implications that could affect the level of preparedness and motivation of the teachers. Having in mind the differences in economic development, social settings, and overall environment between these two countries, this study focuses on collecting quantitative data using surveys as well as qualitative data using interviews. The following research questions are addressed alongside the study's primary objective:

RQ1: Is there a significant difference between the teachers' attitude towards AR?
RQ2: What is the teachers' attitude toward the contribution of AR to the development of students' skills and towards receiving training and resources for using AR in education?
RQ3: Is there a difference between teachers who teach natural science subjects compared to social science subjects when it comes to the attitude and perception of AR utilization and the need for professional development?

This paper continues with the theoretical and methodological foundations that guided this study, which are followed by the presentation of our collected data.

Furthermore, we provide a quantitative and qualitative analysis of the collected data. The paper is concluded with a discussion of the results as well as future avenues for continued research.

2 THEORETICAL FRAMEWORK AND LITERATURE REVIEW

The following sections will examine the theoretical framework that informed this study as well as previous works that are relevant to the topic of augmented reality.

2.1 Technology-mediated learning and engagement theory

This study was guided by the technology-mediated learning (TML) framework [11], following the learning theory known as the engagement theory [12, 3]. Technology-mediated learning is defined as an educational environment where the learner's engagement with educational activities (such as readings, assignments, exercises, etc.) peers and/or teachers is facilitated through the use of advanced information technologies. The main components included under the TML framework consist of technological properties, pedagogical approaches, cognitive processes involved in learning (such as motivation), and educational achievements attained within a specific learning context [11, 13].

Several studies have yielded contrasting findings on the impact of TML on learning effectiveness. Hu and Hui discovered no substantial impact of TML on learning effectiveness [14]. Conversely, Hung et al. [15] and Dalipi et al. [10] demonstrated that TML has a beneficial influence on learning motivation, while Chou and Liu revealed that TML enhances learning performance [16]. In the present work we leverage TML to examine the teachers' attitudes and motivations for integrating AR in education settings.

The engagement theory focuses on cognitive processes, including those related to problem-solving, decision-making, and assessment. The theory suggests that participation may be achieved by three key components, namely, relating, creating, and donating. Relating emphasizes the significance of attributes such as effective communication and adept social skills deemed vital to collaborative endeavors. Under such circumstances, students exhibit a heightened level of motivation towards the acquisition of knowledge. In contrast, the concept of creation is often linked to the qualities of creativity and intentionality within project-based methodologies. When students have the chance to independently conceptualize structure and execute their projects, they are more likely to cultivate a sense of ownership over the project and their own educational growth [16, 17]. Finally, the concept of donation is linked to the process of acquiring knowledge within a broader community context. When students are actively involved in project-based learning, they have a tendency to foster their interaction, cooperation, and teamwork skills. The acquisition of these soft skills is crucial once entering the professional environment. This concept is in accordance with the principles of meaningful learning and constructivist pedagogy [18, 19].

Engagement within an educational setting has a dual conceptualization, including both involvement in the whole schooling experience and active participation in academic tasks within a specific session [20]. The present study focuses only on the latter aspect, namely the interest in schoolwork. Findings have shown a positive correlation between engagement and academic accomplishment, suggesting that engagement might serve as a predictor of future success and achievement in

educational settings [20]. Additionally, engagement has been associated with lower rates of dropping out of school [21].

There are several approaches to conceptualizing the concept of engagement. In their seminal review article, Fredricks et al. [3] provide a comprehensive description of three distinct categories of engagement, i.e., behavioral, emotional, and cognitive. The behavior category refers to the act of actively engaging in academic, social, or extracurricular activities. The emotional category of engagement examines the emotional responses, including both positive and negative emotions that individuals experience in relation to teachers, classmates, academics, and the school environment. Finally, the cognitive category refers to the inclination to invest the necessary effort in order to understand intricate concepts or acquire challenging abilities. The present research has considered the three components in order to investigate teachers' perceptions and attitudes towards the use of AR in educational activities.

2.2 Previous studies related to AR in schools

Augmented reality has attracted significant attention from several academic areas. In its basic definition, AR facilitates the interaction between real-life objects and virtual objects, therefore actively engaging students in the process of gaining knowledge [22]. AR enables the dynamic manipulation of the location and orientation of virtual items, contributing to a better understanding of the learner's physical environment. According to Shadley et al. [23], this fosters the development of modern educational settings that enhance learning opportunities.

Some practical examples of AR applications include Pokemon Go, an interactive game that overlays virtual creatures onto the real world; Hololens, a wearable device that enables users to interact with holograms; the IKEA mobile app, which allows users to virtually place furniture in their homes; and the Loreal make-up app, which uses AR to simulate different makeup looks on users' faces. The educational use of AR has been evident since its inception [24]. Research-wise, significant reviews of the utilization of AR in the field of education have primarily concentrated on its pedagogical advantages [25, 26]. Additionally, scholarly investigations have explored the categorization of AR methodologies in educational settings [27] as well as the contextual factors and distinguishing features associated with their implementation [28]. Other directions are related to usability.

Other research examples include a study conducted by Song et al. [29] on the use of AR in the context of learning, which has shown to enhance engagement in language acquisition. Similarly, research done by Wei et al. [30] used the Partial Least Squares-Structure Equation Modeling (PLS-SEM) approach in order to examine the inclination of educators to adopt AR as a prospective instructional aid. The study indicates that there is a strong correlation between educators' levels of creativity and their desire to adopt novel practices or methodologies. The constructs of perceived ease of use (PEU) and perceived usefulness (PU) have influenced the moderation of this phenomenon. Additionally, research done within the context of Palestinian characteristics has confirmed that the use of AR technology within an educational setting can yield several innovative benefits in enhancing the development of twenty-first-century skills among K-12 students [31]. The statement effectively underscores the need to motivate educators and students to use AR as a tool for enhancing learning. It provides a crucial platform for discourse among educational institutions and educators about the implementation of AR. A similar study [32] focused on female students' attitudes toward the use of AR to learn chemistry. The results showed that

utilization of AR in learning topics such as atoms and molecules reactions has a positive impact.

3 METHODOLOGY

The research was undertaken within the project titled EDUTAIN. This project received funding from "The Swedish Foundation for the Internationalization of Higher Education" and was specifically designed to enhance educational quality and improve school conditions in developing nations. The project started in February 2022 and spanned a period of twelve months. During the month of May in the year 2022, a group of educators and researchers from Palestine visited Linnaeus University, an institution of higher education located in Sweden. A series of academic events, including lectures, seminars, and tutorials, were arranged to explore emerging educational technology and ideas. These events also facilitated interactions with teachers from North European country's K-12 educational institutions.

3.1 Research approach

According to a preliminary field study by the researchers in both countries, it became clear that the schools in question benefited significantly from widespread community support, particularly in the form of educational resources such as modern classrooms and innovative teaching tools. Nonetheless, a discrepancy existed in the acceptability and use of these tools, particularly in the context of educational technology, where only a limited number of teachers and students had made use of them. Also, it became clear from the report that the researchers presented at the joint workshops held in Jordan in October 2022 that there is a significant lack of an adequate AR technological infrastructure in schools in the country with low-performing economy.

Motivated by these initial observations, the present research used an explanatory sequential mixed-methods approach, including both a survey and semi-structured interviews. According to Creswell and Creswell [33], the research strategy entails the sequential collection and analysis of quantitative data followed by qualitative data within a single study. The underlying rationale of this technique is that the use of quantitative data and its subsequent analysis contribute to a thorough understanding of the study subject. In contrast, qualitative data and its analysis serve to elucidate and provide a deeper understanding of the statistical findings by examining the perspectives of the participants [33, 34]. The diagram illustrating our employed methodological approach can be seen in Figure 1.

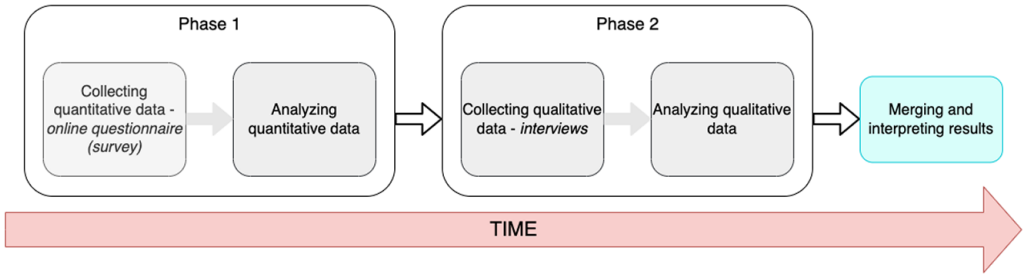

Fig. 1. Research method adopted in the study

3.2 Participants and study settings

The study's participants consisted of K-12 teachers from schools in two different education systems, i.e., within an education system in a high-performing economy, i.e., Sweden, and an education system in a low-performing economy, i.e., Palestine. Convenience sampling was used in the present investigation. This methodology enabled researchers to get a relevant sample efficiently and conveniently. Furthermore, it allowed researchers to have access to a substantial number of sample sets [35]. The use of this particular sample strategy was deemed favorable due to the willingness of the chosen teachers to actively engage in the research. In particular, the schools in Palestine were selected because one of the researchers had been collaborating with their teachers. In total, 87 teachers from both Sweden and Palestine answered the survey, whereas four teachers from Palestine additionally participated in a semi-structured interview. After collecting the data from the survey, interviews were performed to find deeper insights into the participants' experiences and perceptions and to help interpret and enrich the statistical results.

3.3 Survey details and data analysis

The education and specialization backgrounds of the teachers taking part in the survey are presented in Table 1. As can be seen, the participating teachers in this study had expertise and teaching experience predominantly in the fields of natural science education, social science, and physical education, among others.

Table 1. Teachers' expertise and the subjects taught

Country	Natural Sciences	Social Sciences	Physical Education	Other/Unspecified	Total
Sweden	22	8	2	0	32
Palestine	27	18	0	10	55
Total	49	26	2	10	87

The examination of teachers' opinions and attitudes towards AR, as well as their willingness to include it in their future teaching practices, provided valuable insights into the potential benefits and challenges of integrating AR in education. This investigation provided a comprehensive understanding of the possibilities and obstacles associated with AR in education, considering the viewpoints of teachers. Throughout the research process, ethical concerns, as outlined by Creswell and Creswell [33], were followed.

In due course, a total of 87 teachers (32 from Sweden and 55 from Palestine) engaged as participants in the survey research. Among them, the majority were female teachers. The survey was administered during the 2023 spring semester. Prior to undertaking the survey, participants were provided with an information sheet that outlined the importance of maintaining anonymity and addressed ethical issues. Additionally, the provided information explained that participation in the survey is voluntary and emphasized that the findings will only be disseminated in an aggregated manner. Moreover, it assured that complete confidentiality was to be maintained regarding the survey results. The survey has a total of 23 items, of which 22 were five-point Likert scale questions. The survey is categorized into four distinct sections. The first section of the survey consisted of inquiries about participants'

attitudes towards the utilization of AR [36], including the topic they teach. The subsequent section included queries pertaining to the professional development of teachers [37]. The third section of the survey included inquiries pertaining to the participants' desire to use AR [38, 39], while the final section of the survey comprised queries pertaining to the ease of accessing AR [38, 39, 40, 41]. The survey structure and its questions are presented in Appendix 3.

The statistical analysis of the survey results was conducted using the IBM SPSS software. In order to assess the internal consistency, the interpretation of the results was conducted through the utilization of Cronbach's alpha. The researchers found a Cronbach's alpha coefficient of 0.884, which is higher than the commonly recognized threshold of 0.700. This indicates that the scale used in the study has good internal consistency [42]. The exploratory factor analysis to assess the validity of the study was used.

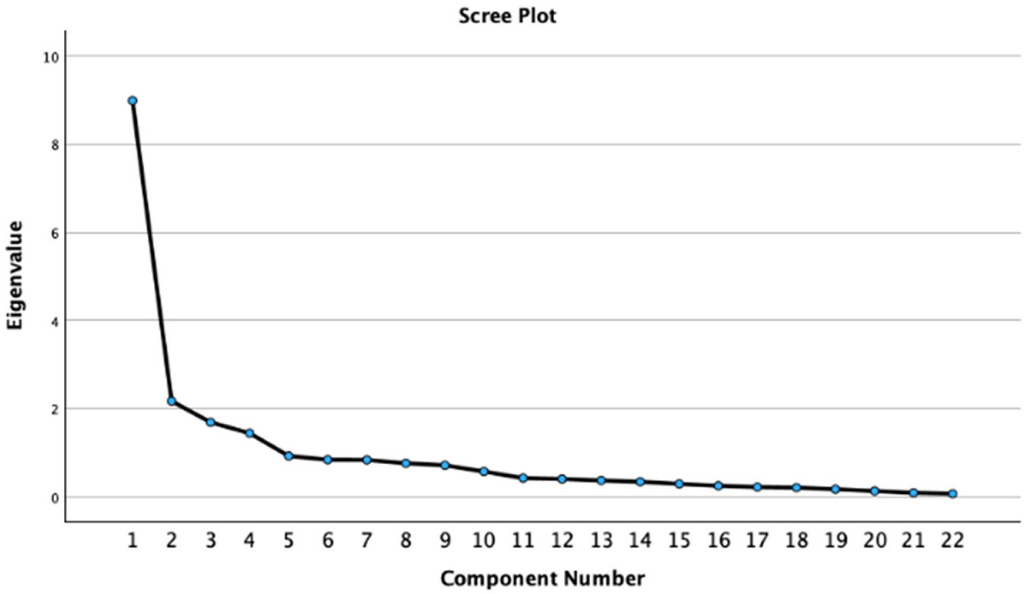

Fig. 2. Exploratory factor analysis

As shown in Figure 2, based on the eigenvalues and the proportion of variance accounted for by each factor, four factors were identified as the most significant (see Appendix 1 for additional results). These factors account for 65% of the total variance. The Kaiser-Meyer-Olkin (KMO) measure and Bartlett's sphericity test were used to assess the appropriateness of sample size and homogeneity. In the present scenario, as shown in Appendix 1, a KMO value of 0.845 indicates that the sampling is adequate. Additionally, Bartlett's test of sphericity yielded a statistically significant result ($p < 0.05$) [43]. This represents the first phase of the study, and the focus is on statistical data analysis.

3.4 Interview protocol and data analysis

In addition to the quantitative part, as indicated in Figure 1, this study also incorporates the qualitative research approach, pertaining to the second phase. Four teachers from Palestine took part in semi-structured interviews conducted on school premises during the period 21.05.2023–30.05.2023. Each interview took, on average,

50 minutes. Participants freely chose to participate in the research by giving clear verbal consent to participate and recording the interviews beforehand. In Table 2, we provide details about participants, such as the subject they teach and the city where the school is located. The following five questions guided the interviews:

- Have you heard about AR and its implications in the classroom? If yes, how did you learn about it?
- What are your perceptions on the integration of AR into teaching and learning activities? Why? Please explain with examples!
- How would you plan to integrate AR in education? Can you explain with examples?
- What would be your strengths and weaknesses of using AR models in the classroom?
- What kind of support system does your school have in facilitating teachers on using AR technology in the classroom?

The analysis of the interview data started by reading and re-reading the interview transcripts multiple times to get familiar with participants' statements and opinions. Thematic analysis was adopted as a method suitable for interview data, and we closely followed the protocol used by Braun and Clarke [44]. During this process, codes were identified and highlighted to indicate the relevance of some of the topics discussed. Later, these codes were grouped into emerging themes, as shown in Figure 4. Finally, the six themes are described in Appendix 2, complemented by actual comments given by interviewed participants. In order to provide confirmability, the data analysis process included a demonstration of the processes taken during data collection, providing assurance that the data were not subject to the researchers' subjective interpretation or imagination [45]. The process of data analysis for interviews was conducted independently and later combined by two of the authors of this paper.

Table 2. Teachers' expertise and the subjects taught

Participant	Subject
P1	Biology
P2	Math and technology
P3	Chemistry
P4	Technology

4 ANALYSIS AND RESULTS

In this section, we provide the analysis and the findings obtained from the quantitative as well as the qualitative approach.

4.1 Quantitative analysis

Within the scope of the study, the attitude levels of the teachers were determined. Detailed information on the overall teachers' attitude towards AR, its contribution to the development of students' skills, and the need for professional development is given in the following subsections.

In order to determine the attitudes of teachers from both Sweden and Palestine towards AR (RQ1), an independent sample t-test was conducted, and the results are presented in Table 3.

Table 3. Differences in attitudes towards AR

	Country	M	SD	t	p
Attitudes	Sweden	3.44	1.15	5.81	.000
	Palestine	3.99	0.84		

Table 3 shows a statistically significant difference in teachers' attitudes about AR ($t = 5.81$; $p < .05$), with teachers from Palestine expressing a more positive view of AR-supported learning. This attitude can be associated with resource constraints and the local context.

Descriptive statistics were used to determine the attitudes of teachers towards the impact of AR on the enhancement of the skills of students and towards the need for training and professional development for utilizing AR in teaching (RQ2). The findings are shown in Figure 3 and Table 4.

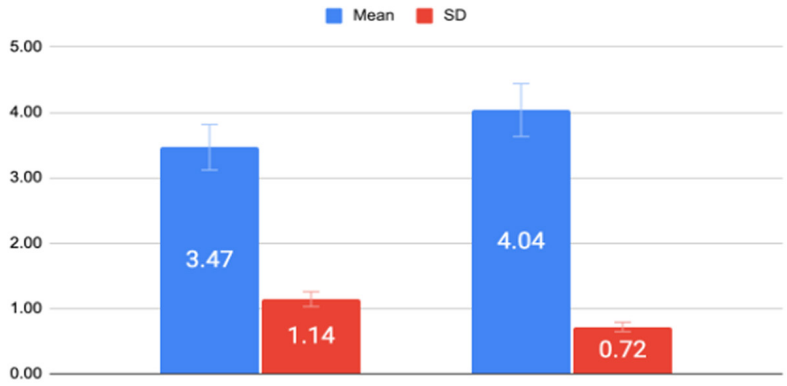

Fig. 3. Attitude of teachers on AR contribution to developing students' skills

According to the results, it was observed that teachers from Palestine exhibit a higher level of optimism ($M = 4.04$, $SD = 0.72$) with regards to the influence of AR in the enhancement of students' skill development. In order to reveal whether there is a significant difference in the teachers' attitude in relation to receiving training and resources for using AR, an independent t-samples test was conducted, and the results are presented in Table 4.

Table 4. Differences in attitudes towards training and resources for AR-supported learning

	Country	M	SD	t	p
Attitudes	Sweden	3.86	1.06	2.48	.000
	Palestine	4.08	0.79		

As can be seen from Table 4, there exists a statistically significant difference in the attitudes of teachers when it comes to receiving training and resources for utilizing AR in education ($t = 2.48$, $p < .05$). In this context, teachers from Palestine show a greater inclination towards receiving professional development opportunities and training focused on effectively incorporating AR into the educational process.

In order to answer RQ3, we conducted an independent sample t-test by merging the results from two countries and grouping them into two sample categories, i.e., teachers with a natural science background versus teachers with a social science background. The results are presented in Table 5.

Table 5. Differences in attitudes of teachers with natural versus social science background

	Subject	M	SD	t	p
Attitudes	Natural science	3.97	0.89	0.77	.43
	Social science	3.92	0.87		

As can be observed from Table 5, there is no statistically significant difference in the level of attitudes between teachers with natural and social backgrounds when it comes to professional development ($t = 0.77$, $p > .05$). Thus, teachers who have a social science background have more negative attitudes toward receiving training and professional support for using AR in education.

4.2 Qualitative analysis

An important insight from the survey was that respondents from Palestine, compared to those from Sweden, were more positive towards using AR in their teaching activities. To further get insights on this positive attitude, we gathered qualitative data using interviews with teachers in Palestine. The interview outcomes address research questions 2 and 3, and as such, they complement the quantitative analysis and results pertaining to these two research questions.

The analysis resulted in six themes that provide highlights from the interviews. After a few iterations between the process of developing codes and themes, we show in Figure 4 an affinity diagram of the themes. The list of codes that came out from analyzing interview transcripts and which were then grouped into themes is shown in Appendix 2. In this section below, we elaborate on each theme and support it with actual comments from participants.

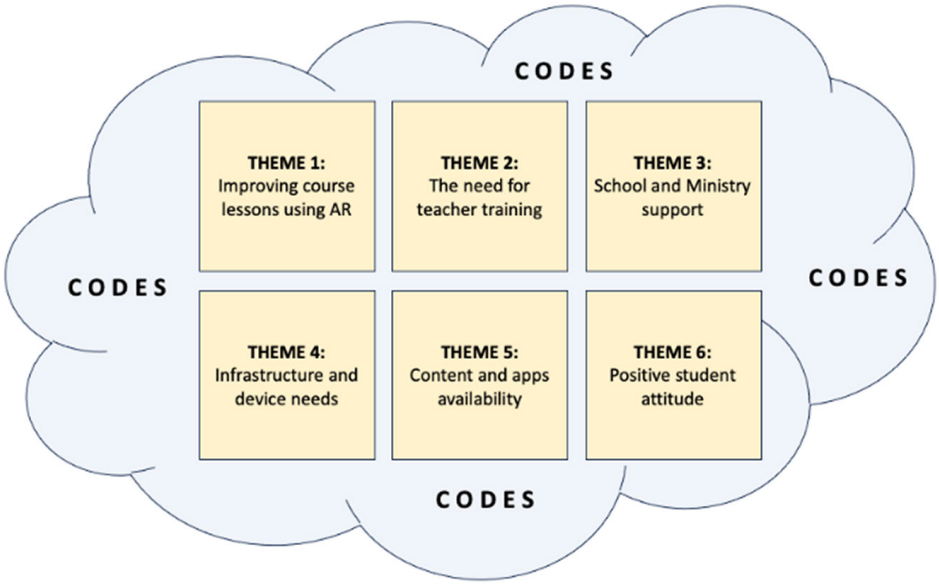

Fig. 4. Depiction of themes using an affinity diagram

Theme 1: Improving course lessons using AR. The interviewed teachers see great opportunity when using augmented reality to improve lessons in their courses. By improving the practical side of courses, AR could be used as a mechanism to visualize and show concepts in different courses, such as biology, for instance, to show animal classification, skeletons, and human body parts; chemistry, to visualize atoms; and engineering, to show 3D drawings and show objects superimposed in real environments, etc.

"Augmented reality applications allow seeing three-dimensional environments such as volcanoes, skeletons, and planets as if it brings the imperceptible things closer to the student and makes it easier for him to imagine and perceive them in a fun and exciting manner" – P3.

"Augmented reality applications give us ease in explaining this lesson; when I want to explain this lesson, I only need a tablet device, element symbol cards, open the application, and point the mobile phone camera towards the card, and it will show us the element and the nucleus of the atom and the electronic distribution of electrons (levels). It had a great impact on the student while seeing the electronic distribution (orbits) of these electrons for these elements and imagining how their image will be, bringing the meaning closer to the student" – P1.

The teachers highlighted that AR could be used in unofficial courses but also courses that are given as part of the regular curriculum, especially in higher grades (6 to 11). In a way, AR could be used in any course where the visualization of results is seen as a way to improve student imagination to learn concepts.

"The ability to imagine, ability to visualize the result. ... The student points the camera with his mobile or smart device on this two-dimensional diagram, then it shows him on a three-dimensional form; the student was able to link the data and the result directly. Augmented reality helps with the issue of imagining the three-dimensional shapes" – P2.

The teachers also suggest that AR could be used to transform traditional textbooks, and the simplest way could be to provide a link that takes students to an AR app within each lesson.

"Make the traditional textbook active. It provides very enjoyable activities and events for students" – P3.

All teachers expressed much need for the AR technology to improve their lessons, as one teacher said:

"We needed this technology and we needed to display the scientific structures clearly so that we could communicate the information better during the lessons" – P1.

But also, AR proved to be helpful during the COVID-19 pandemic when students were studying from home:

"This technology has a major role in communicating information and interacting with students while they are at home during the Covid 19" – P1.

Theme 2: The need for teacher training. Another theme that came out of the data analysis of the interviews is in relation to the comments teachers made about the training needs when it comes to learning about AR. Most teachers said that it takes personal effort to learn about AR, for example, by watching YouTube tutorials.

"I learned about these applications through YouTube, which contains a detailed explanation of these applications and how to download them." – P3.

As such, most teachers shared the opinion that a real challenge is the lack of training offered about the use of AR and its integration in courses.

"We cannot create environments that are in line with our courses, so we are satisfied with what is available online due to the lack of sufficient training for us which is based on personal effort." – P3

Teachers typically find apps on their own, learn how to use them, and then improvise in different ways to integrate them within the courses they teach. Some teachers have the perception that AR technology is difficult to learn; thus, training is needed. One teacher got inspired by the Pokemon game and how the same approach could be used in their courses.

"I learned about AR through the world Pokemon game that became famous in 2013, which requires opening the phone's camera and wandering around to find Pokemon characters." – P4.

Theme 3: School and ministry support. In general, the ministry and schools from which the interviewees came support the use of technology in education and even highlight the importance of integrating AR into education.

"Now the ministry seeks for this technology to integrate education with technology and traditional education." – P1.

However, many initiatives are individually done by teachers and not taken by the ministry, as one teacher stated:

"There was a course by the Gaza Directorate by the department of educational supervision on augmented reality, so I had a desire to attend this course because of my interest in this topic." – P1.

Additionally, many schools lack the knowledge on how this should be done. Moreover, schools need to provide adequate financial support for buying tablets and other devices needed for the integration of AR into courses.

"... we need financial support, for example, providing tablets is a problem when there are six devices, so we need more financial support so that we can have every student or every two students using the device comfortably ..." – P1

Considering the lack of budget that schools face, teachers and the schools often look for external funding in order to supply classrooms with suitable devices needed for utilizing the AR technology.

"... the school that it obtained a project for the digitization of education later in the same year [2017], from which the school obtained 249 laptops and tablets." – P4.

Theme 4: Infrastructure and device needs. The interviews revealed that there are specific needs in terms of devices and infrastructure in order for the AR technology to be utilized in courses. However, it seems that the needs are different, and strategies vary among schools. Some schools highlight the need for a strong internet connection in order to be able to use the AR apps.

"... the problem of Internet speed remains." – P4

In other schools, they state that the internet connection is strong enough, but they lack suitable devices that can run AR apps. Another teacher stated that the internet is not essential because most of the apps work offline, and the Internet is not a requirement. Some schools utilize students' smartphones in order to direct them to install the AR apps and use them in class. But this does not always work since some schools have a no smartphone in a classroom policy, which makes it difficult for students to use their own devices.

"... some schools do not allow the use of smart devices in the classroom because they are afraid of some other aspects, such as the student being distracted, photographed or opening unwanted applications." – P2

Additionally, although all students have smartphones, it could be an old device, which might not run AR apps that typically require decent processing power. Some schools have several iPads that were obtained from other previous projects, and they typically group students and give them one iPad to work with since they do not have one iPad per student, as one participant commented:

"The school provides a specific number of iPads, so I used to bring five iPads with me and divide the class into groups, and each group had an iPad." – P1.

Theme 5: Content and app availability. A major challenge when it comes to integrating AR technology in courses is the availability of apps and content. Luckily, many teachers commented that usually they can find apps developed already by others and that are freely available and can be used in their courses, as one participant said:

"Most of the applications are ready, there are some applications for free and there are some of them paid, but the free applications are many and benefit the purpose excellently." – P1.

One teacher mentioned that she has identified 30 apps that are free and that she uses in her courses.

"I have about 30 applications, including applications for chemistry, biology, and life sciences." – P1.

Additionally, most of these apps work offline. However, there are teachers who think that there is a need for specialized apps, which can't be developed because of lack of knowledge. For instance, the math teacher stated:

"Developing apps needs a specialized person to build them, so most teachers, if their major is not technology, will not be able to do it …" – P2.

The same teacher also maintained that apps typically needed for his course are expensive and also demand high processing power, which sometimes is difficult to use in whatever devices they have available.

Theme 6: Positive student attitude. One common aspect that all interviewed teachers agreed was that students are highly motivated to learn using the AR technology. They maintained that in courses where AR was used to teach lessons, students' attention has increased as well as their participation and interaction, as one participant commented:

"The use of applications helps to attract the student's attention … as well as the interaction of students is improved." – P1

Moreover, using AR helps students imagine concepts in courses that in other ways could be difficult to grasp. All teachers agree that learning using AR is perceived as fun and exciting for students. Some teachers, however, mentioned that in the beginning, using AR is very difficult for students because they lack experience and they find it challenging to understand the new teaching methodology. But once they get to try the technology, they learn fast, and then they enjoy it.

"At the beginning, the students see the topic as new and for sure that they will have difficulties." – P2.

5 DISCUSSION

Based on the principles of engagement constructs specified by Fredricks et al. [3], the current research has shown that AR has the potential to improve educational activities related to teaching and learning. The three distinctive engagement components, namely behavioral, emotional, and cognitive, can be effectively achieved via the use of AR in educational practices and learning endeavors. The following subsections discuss the challenges and prospects of AR utilization among the school teachers.

5.1 Behavioral implications

According to the findings from RQ1, RQ2, and interviews, favorable perceptions were noted among teachers about AR features for successful learning and engagement, with teachers from Palestine demonstrating a more positive attitude. The effectiveness of AR in learning is widely acknowledged in academic literature [46].

This is attributed to the immersive nature of these technologies, which use games, 3D graphics, and digital environments to provide auditory and visual stimuli that promote comprehension and facilitate the acquisition of new skills [47].

Another reason why teachers have a favorable opinion of AR technology is because these tools help students finish assignments by providing them with suggestions and cues [48]. From the findings, it can also be inferred that teachers share the opinion that AR technologies provide advantageous qualities that foster student engagement via enjoyable and stimulating experiences, facilitate creative thinking, and enable meaningful interaction with educational content. The understanding of teachers about the manner in which students will interact with AR is crucial in harnessing its full potential and serves as the foundation for significant advancements in these technologies within developing nations, such as Palestine. These positive experiences could result in increased engagement and beneficial educational experiences [49, 50, 51]. Increased student engagement through AR is also evidenced in teacher interviews. Especially, themes one and six describe how the course engagement had improved when AR was used to explain concepts that otherwise were perceived as difficult to comprehend and visualize by students, which resulted in students having a positive attitude towards using AR in their learning experience.

As also reported in other studies, AR has the capacity to enhance student engagement and motivation. Teachers in developing nations see this approach as a helpful means to sustain students' engagement in the learning process, hence promoting enhanced skill development across many academic disciplines [52, 53].

5.2 Emotional challenges

Teachers generally have a positive sentiment towards the integration of AR in education [54]. Our findings indicate that most teachers from both countries believed that the utilization of AR has the potential to provide enhanced educational achievements. The use of this technology facilitates the creation of immersive experiences and enables the visualization of intricate ideas, hence assisting in the understanding and retention of knowledge.

Although there is a prevailing favorable feeling, it is crucial to acknowledge that the integration of AR may also provide problems and issues, including the need for sufficient training and resources. Nevertheless, teachers generally have a positive sentiment towards the potential of AR to augment the educational experience. Nevertheless, teachers in developing countries often have constraints in terms of resource availability and access to opportunities for professional growth. Thus, teachers may exhibit a greater inclination to use AR due to its potential as a financially viable means of enhancing teaching methods and effectively tackling distinct classroom obstacles [55]. In addition, the educational challenges in developing countries can include unique characteristics, resulting in standardized approaches being ineffective in certain instances. AR provides teachers with the ability to customize solutions to suit their particular circumstances, making it a valuable tool for addressing local requirements [56]. Lastly, the integration of innovative technologies such as AR in education may be seen as a step towards the modernization of educational institutions. Teachers in developing countries may exhibit a greater tendency to use AR as a means of aligning with global educational trends and preparing students for the digital age, and with this, to connect with a broader, international education community, enriching their community of practice [52, 57]. This is further reinforced by interviews we conducted with teachers in Palestine, who, coming from a developing

country, showed great support for incorporating AR in their teaching activities. They, however, also highlight challenges related to infrastructure and devices needed to implement AR curricula as well as adequate teacher training. These aspects are elaborated on in themes two and four.

5.3 Cognitive challenges

Teachers in both countries were found to highlight the need for training on how AR can be integrated effectively in the teaching process. Ariso [58] highlighted the need to cultivate novel epistemic skills in order to effectively incorporate and use AR to achieve desired educational goals. In light of this finding, Yeh and Lan [59] argue that there exists a pressing need for research that prioritizes the teacher's professional development.

It is imperative that while implementing emerging technologies like AR, authorities engage in meticulous preparation and use effective strategies to ensure that the introduction yields favorable outcomes for teachers. This suggests that prior to the implementation of new technological tools and instructional methods, it is important for teachers to possess the necessary knowledge and readiness regarding the use of AR. Hence, while creating instructional activities, it is crucial to use a blended learning strategy that effectively integrates both AR and conventional teaching approaches [60].

The attitude of teachers in developing nations towards acquiring training and resources for the utilization of AR in educational settings can exhibit considerable variation depending on factors such as technological accessibility, understanding of the potential advantages of AR, and the degree of support extended by educational governing bodies [40]. When it comes to the influence of AR in the enhancement of students' skill development, the results indicate that teachers from Palestine expressed a higher level of optimism. Many teachers acknowledge the value of AR being readily accessible through cost-effective devices such as smartphones. The accessibility of AR technology enables students from various socioeconomic backgrounds to access and use AR-enhanced learning, which has the potential to mitigate inequality in education and foster skill development [61]. Research conducted in Sweden has shown promising findings regarding the use of AR solutions in educational settings to enhance students' understanding of the interplay between instructional and entertainment activities inside classrooms [62, 63, 64]. Nevertheless, the integration of AR technology in education is not without its obstacles. One such difficulty pertains to the insufficient integration of pedagogical aspects in the implementation of AR technology [65]. Additionally, the development of sustainable plans, such as curriculums, is necessary to ensure the long-term viability of AR technology in educational settings.

As indicated by the findings from RQ3, teachers with a social science background have more negative attitudes toward receiving training and professional support for using AR in education. In such scenarios, training should be designed so that it aligns with social science teachers' specific pedagogical goals, emphasizing AR's potential for enhancing interactive and experiential learning in their subjects. In addition, with regards to design considerations, there exists a shortage of standardized and cohesive frameworks for the systematic development and evaluation of AR techniques [66, 67]. Support for this can be seen in themes five and three extracted from teacher interviews. While AR apps and content are available, those are not internally designed and developed with the intention of complementing traditional

teaching methods. Instead, teachers try and use them as they see fit, without following any structured framework to ensure the quality of the teaching outcome. This indicates the necessity for schools and educational institutions, including the Ministry, to provide support and strategic planning tailored to actual needs and context.

5.4 Implications and recommendations

This study also serves as a call to action for authorities to provide educators with the necessary pedagogical and technological competencies, along with suitable resources and tools. This will enable educators to effectively implement educational changes that promote more adaptable models and practices. This change would help to promote active learning and encourage students to embrace critical learning skills.

Based on the findings from this study, we provide the following recommendations for educators regarding AR use in K-12 education, with special emphasis on Palestine:

- **Curriculum alignment:** Ensure AR applications are tailored to the Palestine curriculum to make learning experiences relevant and support the acquisition of twenty-first-century skills.
- **Professional development:** The study confirmed that teachers from Palestine showed greater inclination towards receiving professional development opportunities and training focused on effectively incorporating AR into the educational process. Anyhow, providing continuous training to build both pedagogical and technical skills required for integrating AR effectively is necessary. This might include workshops or certifications in digital pedagogy.
- **Active learning implementation:** Use AR to create interactive and hands-on learning opportunities, promoting active learning and enhancing critical thinking skills among students.

On the other hand, concerning the policymakers, we highlight the following recommendations:

- **Resource allocation:** Invest in the necessary tools and technological infrastructure to support the adoption of AR in schools, including devices, software, and support materials.
- **Broader research support:** Encourage and fund studies with a larger, more diverse sample to understand the broader impact of AR on educational outcomes across different demographics and regions.
- **Alternative technology research:** Promote exploration of other technologies, such as VR or AI, for potentially improved comprehension of complex subjects, especially in science and math education.
- **Standardized AR development:** Collaborate with developers to create AR tools that meet educational standards and address curriculum needs effectively.

This study presents significant findings that may be particularly useful to the Palestinian government, educational institutions, teachers, and other stakeholders engaged in the use of AR within the educational sector of Palestine. Numerous studies conducted in contexts comparable to Palestine validate the significance of synchronizing the development of AR applications with the Palestinian curriculum [51, 31, 68]. Schools in resource-limited environments tend to adopt innovative technologies like AR more readily, as these tools offer a way to overcome logistical

challenges and elevate learning quality without extensive infrastructure investment, thus the more favorable perception of AR in Palestine. This study's findings align with the global trend of growing AR adoption in K-12 education, reinforcing its role as an inclusive educational tool adaptable to varying resource levels.

5.5 Limitations and future work

It is important to note that the scope of the results is limited to educational institutions specifically situated in Sweden and Palestine. Furthermore, it is worth mentioning that the role of school management has not been taken into consideration as a variable in this study.

The study was conducted on a limited sample size, which poses challenges in extrapolating the results to a broader population. Hence, it is essential that future research endeavors include a broader range of participants from diverse geographical locations in order to get a more comprehensive understanding of the obstacles and opportunities associated with AR. Moreover, future research may explore the efficacy of alternative technologies in comprehending complex scientific subjects, which may be conducted via experimental design. Such research will delve deeper into the impact of technological infrastructure on AR implementation, and usability issues for AR applications.

6 CONCLUSION

In this study, we examined the implications of teachers' attitudes towards AR and its application within the K-12 educational setting. More specifically, the perspectives of educators about learning, cognitive development, personal growth, social skills, and professional training within the educational domain were investigated. The need for undertaking this study arises from the notion that the adoption of AR in educational settings would be subject to its perceived efficacy in facilitating teaching, learning, and skill acquisition.

The findings indicate that there exist notable differences between educators from Sweden and Palestine in terms of their use of AR for enhancing students' abilities and their access to training and resources for incorporating AR into educational practices. Therefore, it is important for educational institutions and application developers to consider a range of learning and teaching methods, as well as specific needs, throughout the process of developing and incorporating AR into the curriculum.

In conclusion, the study underscores the innovative potential of augmented reality in education, notably in augmenting student engagement and promoting learning outcomes. AR promotes active learning and facilitates the cultivation of essential twenty-first-century skills via immersive, interactive experiences. These benefits are especially relevant for educators and stakeholders in Palestine, since connecting AR with the curriculum may guarantee that the technology functions as an effective instructional tool.

6.1 Conflict of interest

The authors declare that the study was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

6.2 Author contributions

Conceptualization, F.D., and A.E.; methodology, F.D., A.E., M.F.; formal analysis, M.A. M.F., investigation, A.K., F. D.; writing-original draft preparation, F.D.; writing-review and editing, F.D., A.E., M.F., M.A and A.K.; supervision, F.D.; project administration F.D. and A.E. All authors have read and agreed to the published version of the manuscript.

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8 APPENDIX

Appendices can be found using this link: https://github.com/aewais/iJIM-article

9 AUTHORS

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