International Research Journal of
SCIENCE, TECHNOLOGY, EDUCATION, AND MANAGEMENT
P-ISSN: 2799-063X — E-ISSN: 2799-0648
Volume 5, No. 1 | March 2025

The integration of augmented reality tools in South African schools: Selected pre-service teachers' views

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ABSTRACT

This study examines selected pre-service teachers' views on the application of Augmented Reality (AR) tools in South African schools where they were deployed for School-Based education (SBE). Mixed methods were used to collect quantitative data from 80 purposively selected pre-service teachers. A survey questionnaire with a Likert scale with 5 points was used to gather the quantitative data from the 80 participants. Out of 80 participants, face-to-face interviews with 10 randomly selected pre-service teachers were conducted. The results demonstrated that more than 70% of the 80 pre-service teachers disagreed and strongly disagreed that the teachers had a good awareness of and understanding of AR innovation; were ready to adopt AR tools, were competent with these tools, and that their attitudes towards AR were positive. As these participants indicated that difficulties with implementing AR existed at the schools, more than 60% of them agreed that interventions were desperately needed. The study suggests that the schools collaborate with the Department of Basic Education in South Africa and other key stakeholders to ensure that the 4IR resources, in this case AR are adequately funded to enable all teachers, including student-teachers to effectively incorporate them into their teaching and learning activities whilst on School Based Education (SBE). There is need to engage further research at a large scale to alleviate similar challenges at many other schools, thus closing the digital divide that could be existing between south Africa and other countries.

ARTICLE INFO

Received : Jan. 4, 2025
Revised : Mar. 18, 2025
Accepted : Mar. 31, 2025

KEYWORDS

Augmented reality, Educational institutions, Fourth industrial revolution, Integration, School-based education

Suggested Citation (APA Style 7th Edition):

Moila, O. (2025). The integration of augmented reality tools in South African schools: Selected pre-service teachers' views. *International Research Journal of Science, Technology, Education, and Management*, 5(1), 137-149. https://doi.org/10.5281/zenodo.15193475

INTRODUCTION

Introducing learners to and allowing them to engage with the real world is frequently impractical. Schools have likely even planned instructional trips in the present as well as in the past to meet this demand. However, it is not feasible to send learners on regular field trips to these areas. On the other hand, even though the world has three dimensions, teachers continue to employ two-dimensional resources in the classroom because they are more affordable, more easily obtainable, and more versatile. However, not all educational institutions have easy access to three-dimensional (3D) representations for teaching and learning, even though they are frequently more successful than two-dimensional (Krüger, Palzer, & Bodemer, 2022).

Fortunately, the fourth industrial revolution (4IR) can benefit from augmented reality (AR), which is a three-dimensional virtual environment created by a computer Mooney & Williams, 2024). It has been shown that this technique of visualising virtual data in conjunction with actual, physical data improves attitudes, motivational variables, and learning effectiveness, to name a few educational contexts (Ashrafi, Zareravasan, Rabiee Savoji & Amani, 2022). Augmented reality is an interactive real-world experience that combines data and computer-generated elements that are connected to the outside environment (Dargan, Bansal, Kumar, Mittal & Kumar, 2023). This suggests that overlaying rich content on the real environment enables learners to view it at any time and from any location on web-enabled devices, such as phones and tablets, which is among AR's benefits for schooling.

Literature review

Since technology is flexible and allows students to access course materials and participate in academic activities from any location, frequently at their own pace, its integration into education has increased dramatically. (Ameyaw & Laryea, 2024). Moreover, recent advancements in AR, as well as the introduction of mobile devices have created new avenues for the growth of technology education. Together, augmented reality and mobile tour apps can increase learning engagement and provide tablet and smartphone users more ways to become involved. (Dargan, Bansal, Kumar, Mittal, & Kumar, 2023). As a result of the direct interaction between real-world settings and virtual objects, learners can manipulate virtual information with ease (Klopfer & Thompson, 2020). This facilitates learners' deeper engagement with the educational material, particularly for those attending institutions with limited infrastructure and physical resources. Echoing similar sentiments, research further indicates that AR creates a single, cohesive perception that the user may engage with simultaneously by fusing computer-generated digital content with the user's immediate physical surroundings (Bhowmik, 2024).

However, there are issues with the preparedness of the teachers. Not every teacher is proficient enough to employ technology in the educational setting. Due to a lack of training on educational technology, certain teachers are unconfident when utilising digital platforms. As a result, rather than being incorporated as a fundamental part of the teaching methodology, technology is often used only as a supplemental tool. Teachers may not effectively utilise the potential advantages of different educational technology platforms if they lack a clear grasp of how to integrate technology into the classroom (Solfitri, Siregar, Maifa & Putra, 2024). Still, most educators lack AR experience, more specifically, they lack the necessary pedagogical and technological skills these include the ability to use 3D design software and programme as well as the practical understanding of creating and integrating augmented reality content into the classroom (Belda-Medina & Calvo-Ferrer, 2022). Moreover, these researchers maintain that several obstacles stand in the way of AR's widespread use in education. These limitations include the expense of AR, the scarcity of high-quality augmented reality resources, time constraints, the absence of digital infrastructure, and institutional support (ibid).

Many educational technologies are accessible for usage in Kenya, and their growth is fast. These technologies present an unmatched chance to transform how we interact with, perceive, and use information (Wangui, Ronoh, & Etene, 2024). However, these researchers contend that many teachers may feel intimidated and reluctant to explore the possibilities offered by augmented reality technologies because of their magic and the belief that using them for instruction requires a high level of confidence and technological knowledge (ibid). Accordingly,

these academics also contend that there are several difficulties associated with this significant shift, including to fully utilise technology in education, two major obstacles must be removed: institutional hurdles and the requirement for quality teacher preparation.

On the other hand, Tanzania's Vision 2025 emphasises the necessity to achieve creativity, innovativeness, and a high degree of quality education, which seemingly has not yet been accomplished. To this end, the research findings by Mtebe and Raphael (2023) point out the gaps, including unclear policies, teacher resistance to change, limited electricity, inadequate funds, insufficient bandwidth, and a lack of strategies for adopting new technologies that can support 21st-century learning. It is implied that the gaps place teachers in a difficult situation because the difficulties seem to point in unfavourable directions for developing 21st century skills.

The findings of a study on teachers' attitudes towards using contemporary technology as pedagogical aids support these views, with Ndibalema (2020) claiming that how these tools are used is greatly influenced by the mindsets and opinions of the teachers. and incorporated into teaching and learning. Chisango, Marongwe, Mtsi, and Matyedi (2020) have also highlighted several first- and second-order obstacles to incorporating educational technology in Eastern Cape schools, including teachers' ignorance of the potential of contemporary technologies to improve their pedagogy. Teachers' lack of knowledge about the benefits of educational technologies for teaching and learning was one of the secondary barriers to their adoption (ibid).

But integrating technology—more especially, 4IR tools—into South African schools is a relatively recent strategy that is currently being used in classrooms (Ohei, Mantzaris, Ntshangase, & Olutade, 2023). This new technique was developed in response to the need to improve teaching and learning, which has become a major concern for educational institutions around the world, including South Africa. In the cases of Malawi and South Africa, high levels of economic inequality, uneven internet connectivity, unreliable mobile devices, expensive internet data, and inadequate electricity distribution are the reasons why their 4IR policies initially recommended combining print and electronic media (Chibambo & Divala, 2022). The DBE in South Africa insisted that 4IR should be taught in primary grades despite these issues, as it is envisaged that these tools will enhance users' skills, produce a digitally and information-literate society that is prepared for the workforce, and make it easier for that society to meet the demands of the 21st Century.

While the Department of Education (DoE) (2004) aimed to reach all South African basic and higher education teachers and learners to be ICT-ready by 2013, to use technology with confidence and creativity to help acquire the information and skills necessary to fulfil personal objectives and contribute fully to society, at the time this study was carried out, this goal had not yet been met. Echoing similar views, Oke and Fernades (2020) contend that even while there is potential to benefit from the predicted advantages of this period, particularly in Africa, the education sector is not quite ready for 4IR.

Even though technology integration in education is acknowledged in South Africa, research indicates that most public educational institutions face significant obstacles in this area. These issues include inadequate staff development leading to a lack of appropriate skills; work overload preventing time for technology use; and multiple learners attempting to use insufficient equipment and related resources at the same time preventing simultaneous access to these tools (Mlangeni & Seyama-Mokhaneli, 2024). This view is also supported in Yusuf, Walters & Sailin (2020) who argue that educational institutions are taking their time integrating this technology into their curricula.

The Department of Education's White Paper from 2004 states that there is a shortage in South African public-school teachers' and learners' capacity to successfully use technology into their lessons. There exists a disparity in the proficiency of teachers and learners regarding using these technologies efficiently, obtaining varied and superior content, producing original content, interacting, and cooperating through digital channels. Considering this, the study's goal was to find out how pre-service teachers felt about using augmented reality tools for teaching

and learning. Its goal was to offer suggestions that, if successfully put into practice, would close, or at least decrease these gaps.

These resources have not yet made their way into the mainstream of schooling, though. The creation and acquisition of pertinent educational content and learning platforms, as well as their alignment with learning objectives and results, represent one of the main problems of augmented reality in education (Meccawy, 2022). Even though creating 3D content, a crucial part of any augmented reality systems, may now be simpler, most developing nations, South Africa included, still find it difficult for teachers to quickly produce engaging information (Ziker, Truman & Dodds, 2021).

Professional teacher development on the use of educational technologies, as well as the benefits of implementing them in the classroom is therefore essential. To this end, the South African government has launched several technology initiatives and programmes in recent years with the goal of supplying schools with the necessary tools and readying teachers and teachers for a learning environment that is enabled by technology (Mhlanga & Moloi, 2020). The goal of these initiatives is to give learners the abilities needed for the digital workplace. Numerous initiatives have attempted to provide technology infrastructure, material, and associated skills to support decision-making processes as well as teaching and learning in schools (Ostrowick, 2021). However, for a variety of reasons, including socioeconomic and user-related difficulties, the researcher observed that teachers as well as learners have not completely embraced these advancements in the setting of this study. Most augmented reality educational solutions rely on plugins or specialised software, which limits the systems' accessibility and usability. Given this, the researcher embarked on this study to find out how pre-service teachers in South Africa feel on the application of augmented reality resources in educational settings where they were assigned for their school-based education. It was anticipated that the researcher would offer suggestions on how to reduce any difficulties while using augmented reality (AR) in the classroom.

RESEARCH QUESTIONS

This study's primary goal was to provide information about the selected pre-service teachers' experiences in the application of augmented reality tools in South African schools. In pursuance of this, the researcher engaged the participants to meet the following sub-research questions (SRQs):

SRQ 1: To what degree are schools proficient in utilising AR innovation?
SRQ 2: How much have schools embraced or rejected AR as a tool for instruction and learning?
SRQ 3: What interventions might be used to help schools successfully incorporate augmented reality into their teaching and learning activities?

THEORETICAL FRAMEWORK

Rogers (2003) proposed the diffusion of innovations theory of learning, which forms the basis of this study. The process by which an innovation gradually disseminates throughout the members of a social system through channels is known as diffusion (Rogers, 2003). Additionally, Rogers (2003) defines an innovation as any concept, procedure, or undertaking that someone or another adoption unit considers to be unique. furthermore, a person's attitude towards a new technology has a big impact on how widely it spreads (ibid). Technology integration is considered innovative by potential consumers, which makes it a technological innovation.

The present study aimed to ascertain the extent of AR integration implemented at the schools under inquiry by utilising Rogers' diffusion of innovation theory, which follows a five-stage procedure. The best theoretical foundation for this study is Rogers' (2003) theory, since the terms innovation and technology are interchangeable. The five steps of the decision-making process include knowledge, persuasion, implementation, and confirmation as presented in the following paragraphs:

1. **The knowledge stage**: According to Rogers (2003), innovation begins with the knowledge stage, during which a person becomes aware of the invention's existence and looks for answers to questions like "what," "why," and "how" regarding it. According to Rogers, the questions consist of the following three categories of knowledge:

- Awareness-knowledge denotes awareness of the innovation's existence. This kind of information has the potential to inspire people to learn more about the innovation and ultimately adopt it.
- Knowledge about how to employ innovations correctly comprises both information and abilities. This kind of information affects how much innovation is accepted or rejected.
- Knowledge based on principles explains how and why an innovation function. Lack of understanding about the "how" and "why" of integrating augmented reality (AR) with teaching and learning could be a barrier that encourages abuse of the innovation or even resistance to its use. The DBE initiatives to use technology as an innovation have been extended to most schools across the nation. Notwithstanding the many obstacles that schools encounter, they should all understand "what" educational technology is and "why" it should be incorporated into the curriculum. To enhance teaching and learning in many institutions, teachers and students still need to be trained on the "method" to use these tools. The lack of varied technology tools in most schools further impedes the development of abilities to use modern technologies in teaching and learning activities.

2. **Persuasion stage:** People go through this stage, which follows the knowledge stage, after learning about the innovation. According to Rogers (2003), the adoption or rejection of an innovation does not automatically follow the development of a positive or negative attitude towards it. In contrast to the knowledge stage, which is more cognitive or knowing-centred, Rogers claims that the persuasive stage is more affective or feeling-centred.
3. **Decision stage:** The individual can now choose to accept or reject the invention. Rogers (2003) defined adoption as making the most of an innovation, whereas rejection is the act of not embracing it. Although AR technologies are being welcomed as a worldwide innovation, its potential has not yet been completely exploited because of the many challenges that schools, especially those in developing countries, face.
4. **Implementation stage:** This is the moment at which the invention is implemented, and this may continue for a considerable amount of time until the innovation ultimately ceases to be a very intriguing and original idea. Furthermore, reinvention, which Rogers (2003) defines as the degree to which a user adapts or alters an innovation during the adoption and implementation phase, is a critical element of this stage. But according to Rogers (2003), there is a degree of uncertainty involved in diffusion. Since the individual might not be certain of the innovation's outcomes, expert help is required to allay concerns and boost implementer trust.
5. **Confirmation stage:** The implementer's mindset is critical at this stage. The individual may encounter contradicting and discouraging ideas about the innovation even while it is currently in use (Rogers, 2003). An individual may choose to continue with the implementation or to cease, contingent on the degree of support and attitude towards the invention.

RESEARCH METHODOLOGY

To evaluate the pre-service teachers' experiences using AR technology in South African classrooms, this study employed a mixed method research technique to gather quantitative data, quantify variables with numbers, and analyse analytical statistics. Purposive sampling was used in the study since it was anticipated that the participants would be interested in the topic and had the requisite knowledge and abilities. The data came from surveys completed by 80 pre-service university teachers. To gather descriptive and explanatory data from 80 pre-service teachers regarding the integration of AR tools in South African classrooms, this study used a case study methodology within a multi-method research paradigm. Since it covers the entire research process, including philosophical presumptions, research questions, design, data collection, analysis, and integration techniques, and reporting structures, the mixed methods approach was chosen over alternative approaches (Creswell & Plano Clark, 2023). This approach entails gathering, evaluating, and combining qualitative and quantitative data into single research (ibid). Compared to qualitative or quantitative research alone, the design offered more thorough evidence for examining the research problem; it also helped to address questions that would not have been able to be addressed otherwise; and its practicality allowed the researcher to apply pertinent techniques, abilities, and thought processes to the problem. All of this was made feasible by interacting with the sample and population.

Population and sampling

The population is made up of all the individuals, occasions, organisations, case files, and other sampling units that are the subject of the study. (Strydom & Van der Merwe, 2025).) In this regard, this study's research setting comprised of 300 pre-service teachers who are enrolled for Technology Education at one university in South Africa. The study employed purposive sampling since this method applies to situations where certain individuals have the required information. Since these pre-service teachers work in the same department as the researcher, convenience sampling was also used, which saved money and time.

Data collection instruments

A 5-pont Likert scale survey questionnaire was designed to gather precise, crucial information about the use of AR for teaching and learning throughout undergraduates' school-based education at different South African schools. The questionnaire's sections were split into two groups. The biographical data contained details like age and gender. Respondents were asked to score the following research assertions on the questionnaire: Strongly Disagree (SD), Disagree (D), Unclear (U), agree (A), and Strongly Agree (SA) by using X in the box next to each statement. The questionnaire data was examined using Microsoft Excel 2016. The study statements were statistically analysed, and the results were then presented in a composite table with percentages and frequencies for readers to easily understand. The frequency was used to calculate the total number of times each character appears in each category on the measuring scale.

The study used semi-structured interviews. To verify, elucidate, and expand on information about the use of AR in teaching and learning activities at the schools, specific questions were posed. A digital recorder was used for all interviews to capture every detail of the conversations that took place throughout those sessions.

Data analysis

The statistician and data analyst from the university's postgraduate support team helped the researcher analyse the quantitative data. To make statistical data clear, controllable, and understandable, the researcher employed explanatory techniques to characterise, analyse, and condense the data into key study features without omitting or distorting important information (Maharana, Mondal, & Nemade, 2022). Frequencies and percentages were used to display the data for easy interpretation by readers. To either support or contradict the previous findings pertaining to this study, the researcher additionally connected these findings to the evaluated literature. Stated differently, this was carried out in a manner that either confirmed or refuted the opinions of the different researchers that were previously mentioned.

Data analysis in a qualitative study essentially comprises integrating the material the researcher collects from many sources into a coherent description of what they will have observed or learnt in other ways (Lim, 2024). At first, the researcher had planned to use Atlas ti 8, a program for qualitative data analysis (QDSA). However, the researcher did not have access to this tool when assessing the data from the qualitative instrument. As a result, the researcher transcribed the information from the individual in-person interviews that were recorded on audio throughout the study's data collection phase. To acquire a broad idea of the participants' perceptions, the first step was to explore the data. This was accomplished by reading the transcripts in their entirety and making notes on any significant words, quotations, comments, or ideas mentioned. Important assertions or descriptions of unique experiences or viewpoints were then coded or grouped into units, with each code corresponding to a unique, non-repeating significant statement of equal importance.

For every significant comment, the researcher ensured preservation of the original wording and sentence structure. Three methods of category nomination were used: deductive coding based on theory, descriptive coding according to the researcher's evaluation of the participants' actual experiences and emotions, as well as in vivo coding based on the participants' exact words (Lim, 2024). To maintain consistency throughout the coding process,

each code was continuously compared to earlier codes. The meaning of each important statement (unit) was specified in the third step, which involved formulating meanings. In the fourth phase, units or codes containing statements with corresponding material were joined together to construct emergent themes based on the summative established meanings. Classifying the emergent themes into a priori meta-themes was the last phase. These were then debated and presented narratively, along with some verbatim.

Ethical considerations

The researcher ensured that all ethical rules were followed throughout the investigation for this study. The process was completely optional, and participants could opt out at any point. Additionally, participants were told that their data would be kept private and that no names would be disclosed. Furthermore, no sensitive topics involving potentially harmful, invasive, or intrusive procedures will be discussed with the participants. In addition, the researcher adhered to the following ethical guidelines for researchers when gathering data for the study:

- Preserving the respondent's rights, interests, and sensibilities.
- Providing the scientific community with a thorough and transparent report of the research findings.
- Making a constant effort to perform scientific study with objectivity and integrity.
- Reducing the chance that the outcomes might be deceptive.
- Making the research methodology known.
- Preserving data in a format that can be easily preserved and properly cited.

This study had to be conducted academically, and the results were to be shared with interested parties and pertinent authorities to raise awareness of the challenges in implementing augmented reality (AR) applications to enhance instruction in South African classrooms. Corrective action will be aided by the recommendations provided by these findings.

RESULTS AND DISCUSSION

Quantitative data

The study's participants had their demographic data gathered using the first sections of the survey questionnaire. Although this was carried out, it had no implications to the findings since they were expected to give their views on how the schools integrated AR into teaching. Table 1 shows the participant profiles below:

Table 1. The biographic data of participants

Gender	Age (18-20 years)	Age (above 20 years)
Female: 53 (66.25%)	0 (0%)	53 (66.25%)
Male: 27 (33.75%)	0 (0%)	27 (33.75%)

Quantitative data

The pre-service teachers were required to mark X on any of the options provided on a 5-point Likert scale to indicate their single reaction to each statement. The responses of the 80 participants to the seven statements are

displayed in figures Table 2 below:

Table 2: Pre-service teachers' responses

Statement: At the school where I did my school-based education….	Responses (frequencies & percentages)					
	SD	D	U	A	SA	Decision
1. the extent of school's awareness-knowledge of the existence of augmented reality innovation in education is good.	49 (61.25%)	10 (12.5%)	14 (17.5%)	4 (5%)	3 (7.5%)	SD
2. the school staff is motivated by AR knowledge to learn more about the innovation and eventually ready to adopt it.	42 ((52.5%)	25 (31,25%)	6 (7.5%)	5 (6.5%)	2 (2.5%)	SD
3. most of school's staff members are skilled to use AR innovation correctly	38 (47.5%)	26 (32.5%)	0 (0%)	7 (8.75%)	9 (11.5%)	SD
4. the school's staff attitudes towards AR integration as an innovation is generally positive	30 (37.5%)	31 (38.75%)	7 (8.75%)	6 (7.5%)	6 (7.5%)	D
5. the school is moving towards the adoption of AR innovation classroom activities	42 (52.5%)	26 (32.5%)	4 (5%)	3 (3.75%)	5 (6.25%)	SD
6. there are various challenges that the schools face on AR implementation	8 (10%)	6 (7.5%)	0 (0%)	42 (52.5%)	24 (30%)	A
7. possible interventions that can be implemented for the schools to effectively integrate AR into teaching and learning activities are urgently required.	6 (7.5%)	9 (11.25%)	2 (2.5%)	30 (37.5%)	33 (41.25%)	SA

The results in Table 2 indicate that on average, more than 70% of the 80 pre-service teachers strongly disagree and disagree with statements 1 to 5, which are: 1.the extent of school's awareness-knowledge of the existence of AR innovation in education is good; 2. the school staff is motivated by AR knowledge to learn more about the innovation and eventually ready to adopt it; 3. most of school's staff members are skilled to use AR innovation correctly; and 4. the school's staff attitudes towards AR integration as an innovation is generally positive; 5. the school is moving towards the adoption of AR innovation in classroom activities. On the other hand,

on average, more than 60% of the 80 pre-service teachers strongly agree and agree with statements 6 and 7, which are and 6. there are various challenges that the schools face on AR implementation; and 7. possible interventions that can be implemented for the schools to effectively integrate AR into teaching and learning activities are urgently required. This is a clear indication that the schools where the pre-service teachers had their SBE are not yet ready to fully integrate AR for teaching and learning. Although the knowledge and persuasion stages in Rogers (2003) might have been realised, the decision, implementation and confirmations stages are yet to be in place. The findings are also echoed in a study on teachers' attitudes towards using contemporary technology Ndibalema (2020), who asserts that how these tools are used and integrated into teaching and learning is greatly influenced by the attitudes and beliefs of teachers. Furthermore, Chisango, et al (2020) have also highlighted several instructional technology integrations' first- and second-order obstacles in Eastern Cape schools, including teachers' ignorance of the potential of contemporary technologies to improve their pedagogy. One of the secondary obstacles to the use of educational technology was teachers' ignorance of their advantages for instruction and learning (ibid). Although the responses from the Likert-scale have no explanations, they still indicate that these schools have various challenges that hinder full adoption AR for teaching and learning.

Quantitative data

The research examined the opinions of some of the participants' views under the subsequent themes that emerged from their responses:

Theme 1:

Constraints on the usage of augmented reality products in educational settings.

The participants were asked to explain how well they felt the schools understood the use of augmented reality tools in the classroom. A selection of their opinions is shown below:

- *I think most teachers are aware of the existence of AR tools, but I am not sure if they are skilled in using these tools. use them for teaching and learning. I have not seen any teacher using in their lessons*
- *The schools may know that a lot of these resources are being used for education, and mostly for gaming, however, they might still need help on how to use them for teaching and learning. The schools need to be assisted for them to be motivated to adopt these tools for teaching and learning*
- *I doubt very much if the teachers at the school where I did SBE are ready for these technologies for teaching and learning. I have not seen any teacher using these technologies*
- *I have not heard or seen any teacher at the school indicating their interest in AR or other modern technology resources. No teacher that I know of at that school indicated their interest in AR or other modern technology resources, therefore adoption could be still a dream*
- *AR seems to be an unknown tool at the school that I was doing SBE, so I am not sure if the teachers are aware of it or not*

Theme 2:

Unverified levels of teachers' skills and attitudes towards AR tools for teaching and learning

The researcher asked pre-service teachers to clarify how much AR skills the teachers processed, as well as their attitudes for teaching and learning with these tools. Some of the views drawn from these interviews about this matter are as follows:

- *Again, I am not sure as I have not seen any teacher using AR for teaching and learning*
- *I do not think there are many teachers who are able to use AR resources as I never saw anyone doing so during my SBE experience at the school. I would not be able to say what their attitudes are like since these tools were not used for teaching and learning*

- *I suspect that very few, if any of the teachers at the school where I did SBE are skilled to use these technologies for teaching and learning. It is difficult to tell or judge their attitudes, it is only them who would express how they feel about AR for teaching and learning*
- *As I said before, no teacher that I know of at that school indicated their interest in AR or other modern technology resources, therefore their ability could be questionable. About their attitudes, I would not know.*
- *Since AR seems not to be an unknown tool at the school that, Ido not think that most teachers are skilled in the use of AR resources in their teaching, moreover, their attitudes towards these tools could be clearer if at all they were introduced to AR for teaching and learning*

Theme 3:

Deterrents and possible solutions to the implementation AR in teaching and learning

The researcher asked pre-service teachers to describe the AR related challenges and suggest possible solutions for the schools where they did their SBE. Some of the observations made about this topic based on these interviews are as follows:

- *I think that there are no resources for teaching and learning using technology. I believe that if all teachers can allow learners to use their cell phones, it could be easier to use AR in the classroom environments*
- *Teachers lack assistance for them to integrate AR tools for instruction. All teachers and learners must have laptops and tablets as well as access to free Wi-Fi*
- *The management and ICT facilitators must help the schools with resources and training for theintegration of AR in curriculum delivery. Teachers need orientation and the provision of all necessary resources*
- *I think they are being neglected by the responsible authorities. probably fund-raising could help the schools to move away from how they are teaching to modern methods*
- *I observed that there is absolutely no Wi-Fi available in the classrooms at the school, so no technology could really be used for teaching and learning. The government must ensure equitable access to resources by all schools*

These results categorically demonstrate that these schools have not yet regarded augmented reality (AR) solutions for teaching and learning as innovative. According to Rogers (2003) in his diffusion and innovation theory, the innovation process starts at the knowledge stage, when an individual learns about the idea and searches for the "what," "why," and "how" answers. Pre-service teachers noticed, though, that since no teacher had been witnessed incorporating augmented reality into teaching and learning, these questions had probably not even been thought through. Furthermore, according to Rogers (2003), awareness-knowledge indicates that one is aware of the innovation's existence, which does not appear to be the case at these institutions. Lack of this kind of knowledge suggests that there is little to no possibility that teachers will be motivated to learn more about augmented reality as an innovation.

Moreover, this theory clarifies that the ability to correctly apply innovations is a combination of knowledge and skills, which influences the degree to which innovations are accepted or rejected (Rogers, 2003). The pre-service teachers in this study underlined that augmented reality (AR) tools were not being used for teaching and learning, but they were unable to confirm the teachers' lack of knowledge of the "how" and "why" of integrating AR with instruction.

According to Rogers' (2003) theory, people move from the information stage, which comes after being aware of the invention, to the persuasion stage. He clarifies that the emergence of a favourable or unfavourable attitude towards an innovation does not always imply its acceptance or rejection. Rogers asserts that the persuasive stage is more emotive or feeling-centred than the knowledge stage, which is more cognitive or knowing-centred. From this angle, the results from the pre-service teachers' perspectives could not confirm whether the teachers' attitudes towards these resources were positive or negative because AR technologies were not incorporated classroom activities at these schools.

It is crucial to pay attention to the assertion that the person has the option to accept or reject the invention at this point in the decision-making process (Rogers, 2003). According to the theory, rejecting an invention is the act of not accepting it, while adoption is the process of fully utilising it. Since these tools were not being used at these institutions, the pre-service teachers reported that they had not accepted augmented reality. Research also show that several obstacles prevent South African schools from implementing augmented reality (AR) for teaching and learning (Chisango et al, 2020).

Furthermore, Rogers (2003) contends that there is a degree of uncertainty associated with diffusion during the implementation and confirmation phases. As the individual may not be confident in the innovation's results, professional assistance is needed to ease fears and increase implementer confidence. To support the schools in achieving this goal, the participants proposed several interventions. These included funding, training on how to integrate AR tools, and equitable access to technology resources, infrastructure, and tools.

CONCLUSION AND RECOMMENDATION

One revolutionary development for the future of education is the use of AR in instruction. This study's substantial research base supports the claim that using augmented reality tools enhances the learning process. Because AR and many other 4IR tools are converging, it is essential that all educational institutions have access to immersive, interactive learning environments that engage learners' senses and encourage deeper knowledge. With the use of augmented reality solutions that bridge geographical and socioeconomic gaps, teachers and learners may both access high-quality education. It has the capacity to drastically alter teaching methods, breaking with traditional pedagogies, and empowering both teachers and learners. However, for these advantages to apply equally to all academic institutions, issues with the availability and use of augmented reality tools as well as teacher preparation for their use must be resolved.

The DBE initiatives to use technology as an innovation have been extended to most schools across the nation. Notwithstanding the many obstacles that schools encounter, they should all understand "what" educational technology is and "why" it should be incorporated into the curriculum (Rogers, 2023). Training on "how" to use these tools efficiently is still necessary for both teachers and learners. to improve teaching and learning in many institutions. The dearth of varied resources in most schools further impedes the development of abilities to use modern technologies in teaching and learning activities, particularly AR in this case, and these challenges are a barrier that encourages resistance to the use of the innovation. This study recommends the alleviation of these challenges as a matter of urgency, until then, Rogers (2003) diffusion of innovation theory which comprises knowledge, persuasion, implementation, and confirmation. Stages cannot be implemented at the schools where the pre-service teachers get the opportunity to have their school-based education. The researcher therefore recommends that schools work with the South African DBE educational technology facilitators and other key stakeholders to ensure that the 4IR, in this case AR resources are adequately funded so that teachers can effectively incorporate them into curriculum delivery. The study's conclusions lead to the following recommendations:

1. The government should work harder to create an environment that supports high-quality teaching and learning if it wants to adopt AR for teaching and learning and reap its benefits. This entails supplying hotspot centres in schools, guaranteeing nationwide network access, and equipping educational institutions with digital resources that support high-quality online experiences.
2. To combat the exorbitant expenses of internet access, the responsible government personnel ought to advocate with Internet service providers (ISPs) for lower internet access fees.
3. The DBE should develop targeted training programs and expedite digital initiatives that are currently outlined as policies to assist teachers and learners in addressing challenges such as information literacy, virtual classroom etiquette, inclusion, and a lack of technological capabilities.
4. To reduce the cost of 4IR technologies, the DBE ought to use open and free software. These would improve how AR is incorporated into instruction.

5. It is recommended that the DBE allocate sufficient funds to upgrade the AR educational infrastructure in every school.
6. The stakeholders in the education industry at all levels should be involved in future research. This will make it possible to fully comprehend the opportunities and difficulties involved in using AR technologies into the classroom.

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