INSTITUTIONS AND SCHOOLS: OVERCOMING HURDLES IN INTEGRATING AUGMENTED REALITY (AR) INTO STEM EDUCATION

Abstract

Augmented reality (AR) is a technology that immerses users in virtual experiences through mobile devices. Its integration into STEM education holds great promise for transforming teaching and learning. However, educational institutions need help effectively incorporating this cutting-edge technology into their curriculum. This paper presents a comprehensive analysis of the critical hurdles institutions face as they navigate the realm of AR in education. Previous studies have identified various obstacles to implementing AR in classroom settings, focusing on the perspectives of students and teachers. However, the root cause of these challenges often lies in the institutions themselves, such as a need for more prepared infrastructure, hindering teachers and students from accessing the technology effectively. This study systematically reviews 40 articles on using augmented reality technology in STEM education to address this gap. Employing qualitative content analysis, the study examines the challenges schools, and educational institutions face in incorporating AR into their teaching practices. The review delves into five primary challenges and 21 sub-challenges encountered by schools and educational institutions when implementing AR in STEM education. Providing teachers with proper instructional technology and adequate training support are significant challenges for institutions. Additionally, the paper explores researchers' efforts to enhance the overall STEM learning experience using augmented reality. Furthermore, the study discusses potential solutions for effectively overcoming these challenges to deliver

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successful AR lessons to students. By addressing these obstacles, educational institutions can unlock the full potential of AR technology, enriching students' learning experiences in STEM fields.

Keywords: augmented reality, STEM education, school, higher education, technology

I. INTRODUCTION

Technology has advanced dramatically, leading to increased curiosity in the virtual realms of augmented reality (AR), virtual reality (VR), and mixed reality (MR). AR, a 3D technology, amplifies our feeling of the natural world with contextual information. It superimposes virtual items over real-world photographs, resulting in a blended environment in which digital content coexists with the actual world (Azuma, 1997; Azuma et al., 2001; Davila Delgado et al., 2020; Goff et al., 2018). This game-changing technology is catalysing transformations in industries ranging from gaming and entertainment to education and healthcare.

For the last ten years, augmented Reality (AR) has been a popular research topic in the education sector, particularly in Science, Technology, Engineering, and Mathematics (STEM) education. AR has the potential to make complex concepts easier to understand and help students navigate scientific principles that may have been overwhelming before. Researchers like Ibáñez & Delgado-Kloos (2018) and Sırakaya & Alsancak Sırakaya (2020) have studied the characteristics of AR applications in STEM education, the instructional strategies used, and the evaluation methods employed. Petrov & Atanasova (2020) have also explored the impact of AR on learning performance in STEM education. Many other studies have investigated the effectiveness and benefits of integrating AR into STEM education.

AR media's immersive features, such as sensory immersion, navigation, and manipulation, encourage positive learning emotions, leading to more efficient and improved outcomes. Despite these apparent advantages, the present corpus of literature has yet to thoroughly investigate the problems and difficulties connected with integrating AR technology into STEM education. These hurdles may include technical constraints such as hardware restrictions or software compatibility issues, educational considerations such as the best way to integrate AR into existing instruction, and numerous costing issues in interactions with this new technology.

This literature review aims to fill the gap by identifying and explaining the challenges faced in AR-based STEM learning environments. It also offers valuable insights into compelling design features and instructional strategies that can improve students' learning experiences in these environments. By addressing these challenges and providing solutions, this review aims to contribute to the creation of immersive and engaging STEM learning environments that help students understand complex concepts.

II. RESEARCH QUESTIONS

The Purpose of this Study was to Examine Three Research Inquiries, which are as follows:

RQ1: What are educational institutions' or schools' primary challenges in integrating augmented reality (AR) into STEM education?
RQ2: What are the sub-categories for the primary challenges?
RQ3: How the primary and sub-category challenges impact the widespread adoption of AR in educational settings. Potential strategies to overcome these barriers will also be examined

to propose viable solutions for institutions seeking to implement AR effectively in STEM education.

To better understand the challenges, we reviewed current literature as the primary source for answering our research questions and gaining insight into the topic.

III. METHODOLOGY

The author utilises PRISMA (Prefers et al. for Systematic Reviews and Meta-Analysis) methodology developed by Moher, Liberati, Tetzlaff, and Atman in 2009. This helps the author systematically locate research papers pertinent to the study. The aim is to gain a better understanding of the difficulties encountered by educational institutions when using augmented reality applications. This paper's research and review process includes several phases, illustrated in Figure 1.

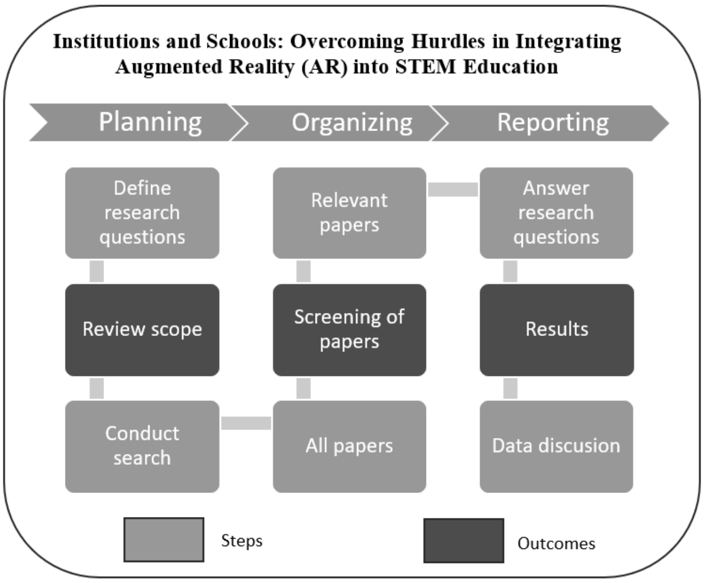

Figure 1: Research methodology mapping

1. **Definition of Research Questions:** The process of defining research questions for this research involves several key steps. First, the author identifies the research topic and conducts a preliminary literature search to understand the research gap in AR related to STEM education. Then, the author clarifies the purpose of the SLR and brainstorms potential research questions that are specific and relevant to the topic. Finally, the author developed the research questions mentioned in section 2.

2. **Review Scope and Conduct Search:** The author selected the research questions and used appropriate and pertinent keywords to conduct numerous searches. To locate pertinent literature sources published in the previous ten years, from 2013 to 2023, an electronic search was conducted using five well-known online research databases, including Web of Science (WoS), Science Direct, Springer Link, IEEE Xplore, and Scopus. The terms "augmented reality" and "STEM" were used in the initial search. The experiment was expanded to discover augmented reality's application in STEM (Science, Technology,

Engineering, and Mathematics) education. Keywords like "augmented reality", "STEM", AND "education" were used in this stage to find the appropriate data types. To find the most pertinent publications, search terms like "augmented reality" AND (STEM OR science OR technology OR engineering OR mathematics) AND (education for primary OR secondary OR higher learning) have also been used.

3. **Screening of Papers for Inclusion and Exclusion:** During this step, the author examined the papers found during their search and utilised specific criteria to determine which ones were relevant to their research goals and should be incorporated into their review. Furthermore, the author came across papers that failed to meet their criteria and thus removed them from their research. This screening approach ensured that the articles chosen for study were both relevant and of good quality. This entails analysing each study's title and abstract to determine whether it fits the eligibility criteria for employing augmented reality in STEM education. This screening method helped ensure that the selected articles for the study were pertinent and high-quality. Only the papers that met the inclusion and exclusion criteria requirements, as in Table 1, were selected for the final reading to extract answers to research questions. Journals that elaborate on STEM education by implementing augmented reality become the focus of this study since many recent studies have shown some limitations in the field.

Table 1: Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Articles have been published in journals from 2013 to 2023.	Studies that are conducted outside of an educational setting.
Articles that have undergone a peer-review process in academic journals.	Studies focusing on professional education do not pertain to schools or institutions.
Articles that are available in full text.	Articles that report on “virtual reality” in STEM learning.
Articles that are written in English.	STEM studies that do not have an augmented reality approach.
Articles that research augmented reality for STEM learning in primary, secondary, or higher education.	Articles related to augmented reality but do not focus on STEM learning.
Research studies that prove educational potential through rigorous research methods.	

4. **Relevant Papers:** After a thorough screening using Figure 2 as a guide, 267 papers on augmented reality in STEM education were chosen out of 848 papers. Another analysis was performed using this amount for works discussing the issues of augmented reality in STEM education. In that investigation, 40 publications were extracted to investigate further the issues educational institutions face while employing augmented reality.

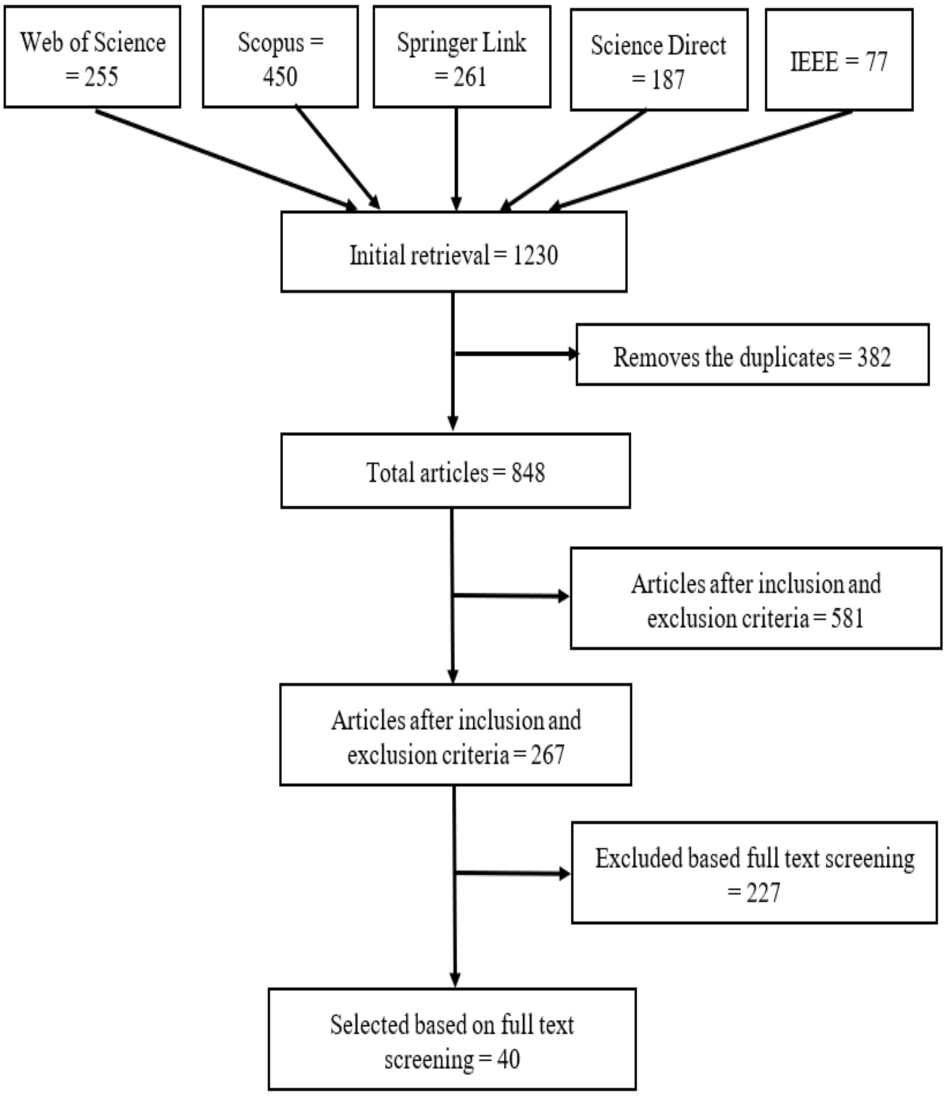

Figure 2: Flowchart of paper selection for analysis

5. **Answer the Research Questions – Characterization of Research Questions:** In this section, the research issue of the study is addressed by exploring the challenges educational institutions face when integrating augmented reality into STEM education. The primary challenges encountered in incorporating AR technology into STEM education will be examined to identify and understand the main hurdles and obstacles institutions face in effectively implementing AR for educational purposes. Additionally, sub-categories of these challenges will be explored to gain a comprehensive understanding of the specific aspects contributing to the difficulties in integrating AR into STEM education. This analysis will help categorise and delve deeper into the underlying issues that institutions encounter. Furthermore, the study will investigate how these primary and sub-category challenges impact the widespread adoption of AR in educational settings. Potential strategies to overcome these financial barriers will also be

examined, aiming to propose viable solutions for institutions seeking to implement AR effectively despite budgetary constraints.

IV. Results

This section answers the research question of this study by discussing the challenges that educational institutions face in implementing Augmented Reality in STEM education. Furthermore, the section analyses the possible root causes and starting points of these identified challenges, their connection with others, and the various approaches to resolving them.

1. **Primary Challenges to Integrate AR into STEM Education:** Five inductive categories were identified as the results of institutional challenges: cost of technology, lack of unsuitable infrastructure, technological limitation, curriculum content, and restriction to the use of mobile phones at school. 'High technology cost' (HTC) is a significant challenge when institutions face purchasing and installing new technologies. 'Inadequate infrastructure' (II) poses another challenge as institutions may struggle to support AR technology. Next, 'technological limitation' (TL) occurs when institutions have limited devices incompatible with AR technology. Also, 'insufficient curriculum content' (ICC) complicates incorporating new technologies into lessons within a budget. Lastly, 'restriction on mobile phone usage' (RMPU) limits AR learning opportunities for students who cannot bring their own devices.

Figure 3: Primary challenges of augmented reality in an educational institution

2. **Sub-category Challenges for Institutions' Primary Challenge**

Table 2: Educational Institutions' Primary And Sub-Category Challenges

Inductive categories (codes)	**Sub-categories**	**Articles**
High technology cost (HTC)	The increased financial price of	
	1. Acquiring a system for AR instruction	Hsu et al., 2017 Petrov & Atanasova, 2020 Stojšić et al., 2020
	2. AR devices & tools	Al-Azawi et al., 2019 Jesionkowska et al., 2020 Thees et al., 2020
	3. Rendering devices	(Rodríguez et al., 2021) (Turkan et al., 2017) (Kang et al., 2016)
	4. AR technology maintenance	Mystakidis et al., 2022 (Turkan et al., 2017)
	5. Integration of AR technology	Sanfilippo et al., 2022
	Economy restrictions for appropriate supplies and materials.	Theodoropoulos & Lepouras, 2021
	AR is not widely adopted in education.	Velázquez & Méndez, 2021
Inadequate infrastructure (II)	The challenge of suitable AR resources for classrooms/institutions	Ajit et al., 2020 Iqbal et al., 2022 Marques & Pombo, 2021
	Unsuitability with current infrastructural condition	Stojšić et al., 2020
	Internet connection of challenge	Küçük et al., 2016 Marques & Pombo, 2021 Mystakidis et al., 2022 (Sırakaya & Alsancak Sırakaya, 2020)
	Insufficient lighting in the classroom	Ajit et al., 2020 Cai et al., 2014 Chang & Hwang, 2018 Gun & Atasoy, 2017 (Liu et al., 2020) Mylonas et al., 2019 Sahin & Yilmaz, 2020 Sırakaya & Alsancak Sırakaya, 2020
	The challenge in detecting marker	Ajit et al., 2020 Mylonas et al., 2019

		Sanfilippo et al., 2022 Sırakaya & Alsancak Sırakaya, 2020
	The challenge in the integration of AR technology	Marques & Pombo, 2021 Mystakidis et al., 2022
Technological limitation (TL)	The challenge in maintaining the stability of the GPS	Ajit et al., 2020 Bressler & Bodzon, 2013 Georgiou & Kyza, 2018 Sanfilippo et al., 2022 (Sırakaya & Alsancak Sırakaya, 2020) Stojšić et al., 2020
	AR compatibility challenge to iOS	(Kramarenko et al., 2020)
	All mobile devices do not support augmented Reality technology	Al-Azawi et al., 2019 Adly et al., 2021
	Incompatible field of view (FOV)	(Deshpande & Kim, 2018) Kapp et al., 2022 Liu et al., 2020 Thees et al., 2020
	The application quickly became a discharge challenge	Marques & Pombo, 2021 (Kim et al., 2018)
	Position tracking & content placement challenge	Becca et al., 2014 Chang et al., 2014 Leahy et al., 2019 (Kaviyaraj & Uma, 2022) Pellas et al., 2018
Insufficient curriculum content (ICC)	Lack of curriculum content	Al-Azawi et al., 2019
	Limited application of the augmented textbooks in practice	Stojšić et al., 2020
	Shortage of learning augmented materials	Lin et al., 2015 Velázquez & Méndez, 2021
	The curriculum scope, restricted benchmark assessments	Theodoropoulos & Lepouras, 2021
	AR is not current practice or not widely used.	Marques & Pombo, 2021 Velázquez & Méndez, 2021
Restriction on mobile phone usage (RMPU)	Mobile phones are forbidden at school	Ilona-Elefteryja et al., 2020 Stojšić et al., 2020

3. **Impact of Primary and Sub-Category Challenges in the Adoption of AR in STEM:** Institutions confront significant obstacles when incorporating augmented reality (AR) into STEM education. The challenges mainly involve financial implications and infrastructure availability, categorised into five areas: high technology costs for AR,

inadequate infrastructure, technological limitation, insufficient AR-related curriculum content and restriction on mobile phone usage. Each category poses specific obstacles to schools seeking to effectively integrate AR technology into their curriculum.

- **High Technology Costs for AR:** One prominent challenge educational institution face in adopting AR technology is the considerable cost of acquiring the necessary equipment. The high expenses of AR technologies result from various factors, including purchasing specialised software and hardware, content production, classroom management, and routine maintenance. As technology rapidly advances, instructors and students in STEM education feel mounting pressure to stay up-to-date with the latest innovations, including AR, to ensure the most effective instruction. Numerous studies, including Hsu et al. (2017), Petrov and Atanasova (2020), and Stojšić et al. (2020), have confirmed that acquiring AR systems for educational purposes can be financially burdensome. This cost factor is regarded as a significant obstacle in modern education. Procuring an AR system for STEM education necessitates investing in expensive specialised gear such as cameras, sensors, and processing units (Al-Azawi et al., 2019; Jesionowska et al., 2020; Thees et al., 2020). Consequently, the substantial financial investment required for implementing AR technology poses a considerable challenge for educational institutions seeking to embrace this innovative teaching approach.

  Limited financial resources can make it challenging for schools and institutions to purchase AR supplies and equipment, exceptionally specialised or high-end items (Theodoropoulos & Lepouras, 2021). Moreover, the fast-paced obsolescence of AR rendering devices may cause institutions to hold back on investing in technology that may need replacing quickly (as noted by Rodríguez et al., 2020 and Turkan et al., 2017). Inadequate government support and funding may pose challenges for certain institutions, limiting their ability to acquire the necessary AR technologies. In addition to the first cost, regular maintenance is necessary to maintain AR technologies' best performance. Performing routine maintenance involves verifying and refreshing the software, performing system diagnostics, and resolving any technical problems (Kang et al., 2016; Mystakidis et al., 2022; Turkan et al., 2017).

  Apart from that, creating AR software is a complex task that requires considerable time and effort, resulting in significant costs. This includes expenses associated with hiring developers, licensing software, and developing customised applications. Also, integrating AR technology in institutions leads to additional expenses, as Sanfilippo et al. (2022) stated. Many students depend on their educational institutions to provide them with access to AR technologies and making devices. These resources are not easily accessible to students at home, as mentioned in studies by Rodríguez et al. (2020) and Turkan et al. (2017).

  Moreover, the utilisation of AR technologies in education is currently limited, as stated by Marques and Pombo (2021) and Velázquez and Méndez (2021). The low adoption rate of AR technologies leads to higher costs in their development and production, as there are no economies of scale. Additionally, the adoption of new technologies is hindered by teachers' and students' inadequate technological skills, which prevent them from effectively utilising these tools (Velázquez & Méndez, 2021). Many educators lack the skills and know-how to employ modern technologies like virtual or augmented reality efficiently. As a result, educational institutions may give more importance to other areas instead of focusing on these technologies. This adds to the overall cost, including the purchase of AR technologies and the provision of training workshops and additional support for effective implementation. (Velázquez & Méndez, 2021).

- **Inadequate Infrastructure:** The financial limitation leads to an inadequate infrastructure that does not fully support the deployment and utilisation of AR technologies. The infrastructure limitation can be examined from the perspective of the suitability of current infrastructure, availability of AR resources, internet connectivity, lighting quality, marker detection and technological integration. Institutions often face challenges in organising AR resources within the classroom, as evidenced by Ajit et al. (2022), Marques & Pombo (2021), and Iqbal et al. (2022). Consequently, this lack of adequate infrastructure can impede the seamless integration of various AR techniques, encompassing marker-based, marker-less, superimposition-based games, projection-based, and browser-based approaches (Radu, 2014). These techniques require various infrastructures or devices to project AR, such as mobile devices, head-mounted displays (HMDs), AR glasses, webcams, and HoloLens (Radu, 2014). Creating AR experiences for different devices requires different development approaches due to their unique features and capabilities. Institutions face challenges in integrating AR hardware due to the diversity of devices, causing a fragmented AR market. Preparing specific device integrations that work seamlessly across all platforms makes it difficult.

While establishing physical classrooms is often feasible in educational institutions, equipping each student with the technological devices for AR implementation becomes costly and challenging. This difficulty arises from multiple factors, including safety concerns, compatibility issues with AR-supported Android versions, and the high cost associated with state-of-the-art or suitable smartphones. Consequently, providing mobile phones to every student becomes an unviable option. Although smartphone-based AR offers user-friendly features with built-in accelerometers and gyroscopes, it limits the scope for physical interaction within the augmented environment. Conversely, webcams such as Kinect and Wii necessitate spacious classrooms to enable a comprehensive AR experience, presenting challenges to educators when evaluating students' comprehension. As Lindner et al. (2022) have emphasised, the provision of smartphones to each student encounters impracticalities due to safety concerns, AR-supported Android version compatibility issues, and the substantial financial investment required for acquiring state-of-the-art or suitable smartphones. Furthermore, to effectively implement AR technologies for learning, especially in STEM education, it is crucial to have access to appropriate physical facilities like large classrooms or labs. Regrettably, current educational institutions have not created learning environments to support these immersive learning opportunities. This hinders students and educators from utilising AR devices and accessories (Ajit et al., 2020; Stojšić et al., 2020).

Aside from hardware obstacles, proper technical setup is crucial for successful AR teaching. This includes a fast internet connection, proper lighting, and a reliable power supply. In today's digital age, a reliable internet connection is crucial for institutions that aim to provide uninterrupted AR lessons to their students (Küçük et al., 2016; Marques & Pombo, 2021; Mystakidis et al., 2022; Sirakaya et al., 2020). However, establishing and maintaining a stable connection can pose a significant challenge. Poor internet connections and disruptions during AR lessons can occur due to limited bandwidth caused by either budget constraints or the number of simultaneous users. For smaller institutions, establishing a stable internet connection can be expensive. This is because they must spend money on infrastructure upgrades, providing high-speed internet access to all students, and maintaining connectivity. Additionally, the physical location of an establishment could create obstacles in obtaining fast internet access because of infrastructure limitations. Institutions face challenges that hinder them from fully maximising the benefits of AR lessons. Various possible remedies exist to tackle this issue, including investing in improved infrastructure, exploring alternative internet solutions, or establishing collaborations with external service providers.

Another infrastructural limitation that classrooms often encounter is insufficient lighting, which directly affects the reflection of light on objects in the environment. (Ajit et al., 2022; Cai et al., 2014; Chang & Hwang, 2018; Gün & Atasoy, 2017; S. Liu & Yang, 2020; Mylonas, Triantafyllis, et al., 2019; Sahin & Yilmaz, 2020; Sırakaya & Alsancak Sırakaya, 2020). AR applications use cameras to identify real-world objects and superimpose digital content onto them. Nevertheless, excessive reflections on object surfaces can impede accurate recognition and tracking. Additionally, poor lighting can also lead to the appearance of shadows, further complicating the AR system's ability to recognise and track object movement. Therefore, arranging classrooms with proper lighting becomes crucial to ease AR detection without shadows and prevent markers from appearing washed out or becoming challenging to detect. This ensures clarity in object recognition and tracking as lighting conditions directly influence the accuracy of marker detection in AR in the environment.

Studies by Ajit et al. (2020), Mylonas et al. (2019), Sanfilippo et al. (2022), and Sirakaya et al. (2020) have highlighted the impact of marker quality on detection accuracy in augmented reality (AR). When markers exhibit low resolution, poor printing, or damage, the software struggles to detect and track them accurately. Camera-related issues, such as improper calibration or technical malfunctions during marker capture, influence detection accuracy. Furthermore, movement and distance affect the software's ability to precisely track markers, mainly when markers are too distant or rushing. Simplicity or lack of distinctive visual features in markers can challenge AR algorithms in differentiating them from similar objects. Conversely, overly complex markers may hinder image processing and feature extraction. Careful consideration of marker quality and characteristics is essential in AR applications to achieve optimal detection accuracy.

The final infrastructure limitation that schools and institutions face is integrating AR technology (Mystakidis et al., 2022; Marques & Pombo, 2021). Integrating AR technology typically involves substantially altering the current infrastructure, such as improving internet connectivity and adding new devices, which can be costly and time-consuming. In addition, a deficiency in AR technology knowledge or skills can be a significant obstacle for educators and institutions. This can potentially impede the successful incorporation of AR into the teaching curriculum. Some educators might not know enough about the latest AR technology or skills to use it efficiently. Suboptimal outcomes and hindrances to the broader adoption of AR technology in education can result from this. To address these challenges, it is crucial for all stakeholders - such as educators, administrators, and technology providers - to work together and create innovative solutions that make it easier to integrate AR technology into educational environments.

- **Technological Limitations:** As discussed above, AR also has technological limitations besides infrastructure limitations. The major technological limitation that educational institutions face is maintaining system stability. Many studies have highlighted the importance of GPS accuracy and reliability (Ajit et al., 2020; Bressler & Bodzon, 2013; Georgiou & Kyza, 2018; Sanfilippo et al., 2022; Sirakaya & Alsancak Sirakaya, 2020; Stojšić et al., 2020). In GPS-based AR applications, GPS signals play a crucial role in accurately tracking locations. However, factors like weather conditions and tall buildings may affect these signals. Most STEM subjects use GPS AR tracking, which is essential to ensure stable and accurate GPS signals. If the GPS experiences any disturbances, it could result in problems such as inaccuracies, delays, malfunctions, or even potential hazards to safety. In order to reduce instances of poor GPS detection, organisations should perform routine maintenance on their AR devices. This can include updating software, replacing hardware, and conducting regular testing.

  The following technological limitation is compatibility issues for accessing AR with different devices. Generally, AR technology is more compatible with Android devices than iOS devices, according to T. J. Lin et al. (2013) and Mystakidis et al. (2021). The availability of Android devices at varying prices makes it a more budget-friendly option for students with different income levels. Compared to iOS devices, they provide superior hardware features at a more affordable price. Institutions may face difficulties deciding between Android and iOS devices for AR-based technology. Android devices offer more options for logging in, compatibility across multiple devices, and syncing and transferring data. On the other hand, iOS demands a new device to guarantee compatibility, which may restrict augmented reality application features. Institutions may face difficulties deciding between Android and iOS devices for AR-based technology. Using iOS devices may not be the best option for learning, but choosing Android devices may pose compatibility issues because of the fragmented operating system across different student devices and versions. Therefore, institutions must comprehensively evaluate compatibility and cost factors when selecting suitable devices for AR-based technology, considering the option to provide access for Android and iOS platforms.

For AR technology to function correctly, it requires specific hardware capabilities, as noted by Adly et al. (2021) and Al-Azawi et al. (2019). Mobile devices must have certain features such as cameras, accelerometers, and gyroscopes. However, not all devices fulfil these criteria, which leads to differences in AR compatibility among various devices. Developers face challenges when creating AR apps that can function smoothly across various devices. Additionally, educational institutions may need to upgrade their students' devices to ensure compatibility with specific AR applications, which can lead to increased expenses and difficulties in adoption.

Devices such as smart glasses that use augmented reality technology face limitations with their field of view compared to the natural capabilities of the human eye. (Deshpande & Kim, 2018; Kapp et al., 2022; Liu et al., 2020; Thees et al., 2020). When it comes to AR devices like smart glasses, one of the challenges they face is their limited field of view. This contrasts with the natural field of view of the human eye, which is much broader and allows us to perceive a more excellent range of visual information. Developers are currently working on creating devices with wider FOVs to improve the user experience. Institutions may find it challenging to pursue this endeavour due to the high cost and impracticality of obtaining more processing power and higher-resolution displays.

Additionally, it is worth noting that AR applications may consume a lot of battery power, rapidly depleting mobile devices' battery life (Marques & Pombo, 2021; S. J. Kim et al., 2018). Augmented reality overlays, continuous camera usage, internet connectivity, and GPS tracking can use graphics processing power, draining device batteries quickly. Institutions, especially those with limited budgets or resources, may find investing in charging facilities or additional devices challenging. Hence, when designing AR space, institutions should consider having multiple plug points to ease the charging process for students.

In addition, AR technology encounters difficulties with position tracking and content placement. This is because it requires precise and dependable tracking of the device's location and orientation concerning the surroundings. Several studies, including Becca et al. (2014), Chang et al. (2014), Kaviyaraj & Uma (2022), Leahy et al. (2019), and Pellas et al. (2018), have highlighted these challenges. One of the challenges is mapping digital content onto real-world objects, surfaces, and environments with precision to ensure proper placement and alignment. Achieving high accuracy can be difficult, particularly in settings where lighting is poor, or shapes are intricate. The performance of AR technology can be affected by the device's processing power, graphics capabilities, and memory, which can impact position tracking and content placement. Institutions should meticulously plan the classroom environment for AR lessons while considering these factors.

To sum up, it is essential to tackle these technological obstacles to develop practical AR applications that provide captivating user experiences for STEM education. In order to overcome challenges and create innovative AR experiences, developers must stay up to date with the latest tools and techniques.

- **Insufficient AR-Related Curriculum Content:** Having examined the challenges posed by high technology costs, inadequate infrastructure, and technological limitations for AR in educational institutions, another significant hurdle in the successful integration of AR in STEM education lies in the insufficiency of AR-related curriculum content. As highlighted earlier, the adoption of AR technology requires careful consideration of various factors, and the availability of suitable and engaging curriculum content is paramount to ensure effective AR teaching and learning experiences.

  The current curriculum mainly emphasises conventional teaching approaches and multimedia tools, like video presentations, PowerPoint slides, and e-books. Despite the potential benefits of using augmented reality (AR) for learning, its implementation in school and higher education curriculum is still limited (Al-Azawi et al., 2019).

  Moreover, the scarce usage of augmented textbooks in practical scenarios, specifically in STEM education, indicates a shortage of AR curriculum, as stated by Stojšić et al. (2020). The reason for this could be regulations or policies that limit the use of specific technologies or mandate special permissions for introducing new STEM teaching tools. Furthermore, there is a reluctance to adopt AR-based curricula in STEM education due to concerns regarding the efficacy of augmented textbooks on learning outcomes and the capability of teachers to deliver AR content.

  Furthermore, the dearth of educational resources tailored for AR contributes to insufficient course material (Velázquez & Méndez, 2021; Lin et al., 2015). Some STEM educators and institutions may not have the budget, resources, or skills to create and execute a complete AR curriculum. Creating AR resources for STEM education is a complex process that involves advanced technology and cooperation between educators and developers. The goal is to produce engaging and relevant materials that align with STEM educational standards. Nevertheless, the lack of learning materials incorporating technology is problematic in incorporating AR into STEM. This makes it difficult for new teaching methods to be adopted and results in less exciting lessons in Science, Technology, Engineering, and Mathematics (STEM).

  The limited use of AR technology in STEM education can be due to restricted benchmark assessments and curriculum guidelines, as noted by Theodoropoulos and Lepouras in 2021. Keeping up with the constant technological progress challenges developing standardised curriculums or syllabuses that can remain effective over time. Therefore, the limited curriculum coverage may result in insufficient training for students and educators on using AR technology appropriately in STEM education. This can lead to less effective utilisation of AR technology in STEM teaching and learning. Additionally, the lack of standardised assessments for augmented reality technology poses a challenge in assessing its effect on student learning. This hinders the ability to pinpoint areas where students excel or face difficulties.

  Furthermore, the AR curriculum is limited because many institutions do not adopt the technology (Marques & Pombo, 2021; Velázquez & Méndez, 2021).

Academics in STEM fields at both lower and higher education levels may have limited expertise in operating AR technologies and equipment. AR technologies are not being implemented in schools due to a lack of awareness and effort from both parties, the school and higher education authorities. Hence, institutions face difficulties justifying the cost of purchasing AR technologies and materials for STEM education due to the curriculum's limited awareness and perceived insignificance of AR technology.

In general, there are several difficulties when incorporating AR technology into education. These include a shortage of curriculum content, limited use of augmented textbooks, a lack of learning materials, restricted benchmark assessments, and a limited presence of AR technology in mainstream STEM practices.

- **Restriction on Mobile Phone Usage:** The final challenge institutions encounter in implementing AR in STEM education is the restricted use of mobile. Students face substantial challenges when it comes to accessing AR lectures due to the widespread use of mobile phones in classrooms. Many institutions have laws prohibiting or disallowing students from carrying mobile phones to school, making it the obligation of the schools to provide smartphones or alternative devices for students to access the AR lessons at their own cost. Mobile phones were initially permitted in schools to facilitate emergency communication between children and their parents (Lin et al., 2013; Mystakidis et al., 2021). On the other hand, concerns have been raised regarding using mobile phones in schools, as they have been known to distract students with social networking and video call programs. These limitations are intended to keep students' attention during teaching and learning, as these technologies can readily attract attention and lead to uncultured behaviours over time.

  Furthermore, allowing mobile phones may exacerbate social differences among pupils from different financial or socioeconomic backgrounds. Some children may flaunt their phones to their peers, creating an unfair atmosphere. As a result, this limitation may hurt pupils' academic focus and performance. Furthermore, the mobile phone ban does not apply only to individual schools but to many educational institutions, as teachers face the challenge of managing distractions and potential misconduct caused by unrestricted mobile phone usage (Ilona-Elefteryja et al., 2020; Stojšić et al., 2020). Concerns about gangsterism, drug peddling, and the risk of accessing restricted websites all contribute to the widespread prohibition of mobile phones in educational settings.

  In conclusion, the restricted use of mobile phones poses a significant challenge for institutions in implementing AR technology in STEM education. While some concerns about distractions and potential misconduct may justify this restriction, it also limits students' access to AR lectures and may exacerbate social differences among pupils. Addressing this challenge requires a careful balance between managing distractions and providing equal opportunities for all students to benefit from the innovative learning experiences offered by AR technology.

V. DISCUSSIONS

The leading challenge schools and institutions face in adopting AR technology relates to equipment, connectivity, and cost. Specifically, the most significant concern lies in providing teachers and students with access to AR technologies. However, the high costs associated with AR equipment often hinder schools from fully incorporating this technology into their educational practices. As a result, schools and institutions grapple with finding viable solutions to overcome these barriers and effectively integrate AR into the teaching and learning processes.

It is common for institutions not to receive enough funding from the government to supply AR tools and technology. Funds are crucial for setting up AR education and supporting teachers and students adapting to AR technology. It is the responsibility of institutions to train teachers in the mastery of AR teaching and the handling of AR technology. This includes providing the necessary training and educational support. Schools and higher education institutions often find hiring private sector experts for teaching and training costly as they lack local AR expertise and internal trainers. Educational institutions must provide students with access to augmented reality (AR) tools during class to avoid any interruptions to the learning process.

In addition, educational institutions encounter difficulties due to the unequal distribution of government funds between schools located in urban and rural areas. Urban schools usually receive more funding because they have a higher capacity and must maintain competitive standards. Rural schools receive only enough funding to cover essential teaching resources and operate without significant issues. In such cases, allotting funds for AR tools to support student learning can be incredible unless a complete overhaul of the entire education system is undertaken to integrate AR into learning.

For AR lessons to be possible, institutions and schools must play a vital role in preparing an adequate supply of materials, tools, applications, and software for teachers and students. Institutions must procure top-notch AR equipment to ensure students receive the best learning experience. Using low-quality AR tools may not help achieve educational goals, which could result in dull and ineffective AR classes. Regarding education, augmented reality (AR) may not be as practical as traditional methods. This is because students may not fully immerse themselves in the learning experience with AR technology.

Providing adequate space for students, locating a marker in a specific area, and periodically evaluating facilities in the classroom will tremendously assist students and teachers in having a better learning experience. As a result, school classrooms must be modernised through dynamic educational processes that allow for modifying educational techniques and resources to promote these essential abilities.

Utilising actual AR cards as a mediator could potentially overcome time and space constraints in the classroom. Students might engage with the AR cards at home, develop their AR-related products out of paper, and bring them back to class. Such tailored and culturally relevant learning resources can potentially increase frequent and profound cognitive involvement in the classroom. Institutions can also incorporate a dashboard within the AR game to help teachers coordinate technology-supported activities in both in-class and out-of-class situations at different levels, such as individual, group, class, and community.

As technology evolves, the education system needs to adapt and advance based on the current technological improvements. Educators and students must learn new abilities to gain access to educational materials. Therefore, institutions must supply teaching materials for digital-native students and non-digital-native professors.

Teachers' scepticism about AR will decrease if educational institutions overcome their problems and fulfil their responsibilities of training teachers and providing appropriate technological infrastructure for AR. Teachers would gain more competence and confidence in using augmented reality technologies while teaching and guiding their students. This enhancement would considerably improve students' AR learning experiences, reducing hurdles, including comprehension issues and cognitive overload. As a result, students' performances will be reflected in their outcomes, assisting teachers in meeting their specified key performance indicators (KPIs).

VI. FUTURE DIRECTIONS/ RECOMMENDATIONS

Augmented reality (AR) in STEM education can effectively engage students and improve their performance. There are a few challenges that must be overcome in order to make sure that AR is utilised efficiently in the classroom.

Future research in STEM education using AR should strive for a more captivating and less mentally challenging approach to learning. Students should be given decision-making experiments that allow them to explore and experiment with correct and incorrect paths to choose the best option. Incorporating message framing into STEM education can create a secure and monitored AR environment that promotes ethical decision-making. Creating AR applications that replace the lead character with the player's self-avatar can aid students in connecting with STEM lessons.

Including multimedia content in AR applications for STEM education can stimulate multiple senses, such as sight, hearing, and touch. This can enhance the learning experience for students. As a part of future research, methods to enhance the kinaesthetic touch and the capacity to access the metaverse using AR technology could be explored. Educators can enhance comprehension of augmented reality (AR) by collaborating with designers to produce AR content that matches the syllabus, is user-friendly, and is precise. Creating online communities can also aid in achieving this goal.

Schools and institutions that adopt AR technology face challenges in effectively managing equipment, connectivity, and costs. Institutions must guarantee that teachers and students have sufficient materials, tools, applications, and software supplies. Improvements to the learning environment, such as providing students with a dedicated space, precise marker locations, and monitoring facilities, can significantly enhance the experience of augmented reality (AR) learning. Therefore, classrooms must transform to enable dynamic educational processes and encourage the development of critical skills.

VII. CONCLUSION

This study examines the current literature on challenges in implementing augmented reality in STEM education, focusing on the perspective of educational institutions. The researchers used Moher's systematic review approach to analyse 40 articles published between 2013 and 2023. Five main categories and 21 sub-categories of challenges have been thoroughly reviewed in this paper. Many institutions encounter cost barriers that prevent them from providing sufficient infrastructure and training. This review aims to guide policymakers, government officials, and institutions on enhancing AR instructions for digital-native students to achieve exceptional digital outcomes and empower the next generation of innovators.

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