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Augmented Reality in Science Education: Current Technologies and Potential for Secondary Education in India

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Abstract

The field of education has witnessed significant advancements with the integration of technology, and one such innovation that holds promise for science education is augmented reality. Augmented reality technology has the potential to revolutionize the way science is taught in secondary education in India. Augmented reality provides students with an interactive and immersive learning experience by combining virtual objects with the real-world environment. This paper explores the current technologies in augmented reality and their potential applications in science education in India. It explores the current landscape of AR technologies, with a specific focus on DAQRI Elements 4D and Exploratorium AR, and their potential applications in secondary science education. Incorporating humanoid 4D+ technology into science education can take the benefits of augmented reality to a whole new level.

Through a scoping review method, 10 articles were analysed to understand the benefits and effectiveness of augmented reality in science education. These studies revealed that augmented reality can enhance students' understanding, engagement, and retention of scientific concepts. Additionally, augmented reality can bridge the gap between theoretical knowledge and practical application by providing virtual simulations and hands-on experiments. Furthermore, augmented reality can cater to the diverse learning styles and

preferences of students, making it a versatile tool for science educators. By leveraging augmented reality in science education, educators in India can create a dynamic and interactive learning environment that transcends traditional classroom boundaries.

Furthermore, the use of augmented reality in science education can also address the challenges faced in resource-constrained settings by providing virtual access to expensive laboratory equipment and facilitating collaborative learning experiences. The use of humanoid 4D+ allows for a more realistic and lifelike representation of virtual objects, creating an even more immersive and engaging learning experience for students. By closely simulating real-life experiences, this technology empowers students to interact with virtual objects, fostering a deeper comprehension of scientific concepts.

Furthermore, humanoid 4D+ technology can offer advanced features such as gesture recognition and real-time feedback, allowing students to manipulate virtual objects and conduct virtual experiments with greater precision and control. This hands-on approach to learning can significantly enhance students' retention of scientific knowledge and foster a deeper appreciation for the subject. This paper explores the current landscape of AR technologies, with a specific focus on DAQRI Elements 4D and Exploratorium AR, and their potential applications in secondary science education. DAQRI Elements 4D offers a robust platform that enables educators to overlay digital content onto the physical world, providing students with immersive learning experiences. Through interactive 3D models, simulations, and data visualizations, students can explore complex scientific concepts in ways that are dynamic and engaging. Additionally, DAQRI's intuitive interface allows for easy creation and customization of AR content, empowering educators to tailor lessons to the specific needs and interests of their students.

Exploratorium AR leverages AR technology to bring scientific phenomena to life, allowing students to interact with virtual objects and environments in real-time. By blending virtual and physical elements, Exploratorium AR fosters a deeper understanding of scientific principles through hands-on experimentation and exploration. From virtual dissections to simulations of astronomical events, this platform offers a wealth of opportunities for students to engage with science in a meaningful and memorable way. The integration of AR technologies like DAQRI Elements 4D and Exploratorium AR into secondary science education holds immense promise for enhancing student learning outcomes. By providing immersive, interactive, and personalized learning experiences, AR has the potential to ignite students' curiosity, foster critical thinking skills, and deepen their understanding of scientific concepts. Moreover, AR can accommodate diverse learning styles and abilities, making science education more inclusive and accessible to all students. This paper explores the current landscape of AR technologies, with a specific focus on DAQRI Elements 4D and Exploratorium AR, and their potential applications in secondary science education.

In conclusion, the integration of humanoid 4D+ technology in science education has the potential to elevate the effectiveness of augmented reality, offering a cutting-edge and dynamic approach to teaching and learning science in secondary education in India. Overall, augmented reality has the potential to revolutionize science education in India by providing an interactive and immersive learning experience.

Keywords: Augmented Reality, Technologies for Augmented Reality Systems, Augmented Reality in Education, DAQRI Elements 4D, Exploratorium AR, Humanoid 4D+ technology.

1. Introduction

In recent years, Augmented Reality (AR) has emerged as a promising technology for transforming teaching and learning experiences in various educational settings worldwide. Particularly in secondary education, the integration of AR has the potential to revolutionize traditional pedagogical approaches by providing interactive, immersive, and engaging learning experiences. In India, where secondary education faces numerous challenges, including resource constraints and outdated teaching methodologies, the adoption of AR technologies could significantly enhance the quality and effectiveness of science education. This research aims to explore the current technologies available, such as DAQRI Elements 4D, Exploratorium AR, and humanoid 4D, and their potential for improving science education outcomes in Indian secondary schools.

The integration of technology tools into the curriculum is becoming part of good teaching (Pierson, 2001). Teachers not only have to spend a good deal of personal time working with computers but also should have a high level of innovation and confidence to use the new technologies that are embedded in contemporary education. The integration of technology also provides a means to enhance student learning and engagement in lectures. Therefore, recent studies have aimed to better understand the applications adapted during lectures from the perspective of students, including multimedia, computer-based simulations, animations and statistical software (Neumann et al., 2011). Research by Geer and Sweeney (2012) showed that the use of a variety of media applications to explain concepts increased the understanding and supported greater collaboration between students.

Augmented reality (AR) is a new technology that has emerged with potential for application in education. While a lot of research has been conducted on AR, few studies have been

conducted in the education field. The number of studies on AR is growing due to the effectiveness of this technology in recent years. AR has been used in different fields in education. In particular, AR provides an efficient way to represent a model that needs visualization (Singhal et al., 2012). AR also supports the seamless interaction between the real and virtual environments and allows a tangible interface metaphor to be used for object manipulation (Singhal et al., 2012).

The National Education Policy (NEP) of a country plays a crucial role in shaping its educational landscape, including the integration of emerging technologies like augmented reality (AR) into learning environments. The promotion of augmented learning in education is aligned with several key principles and objectives outlined in the NEP. Here's how the NEP can promote the use of augmented learning in education:

1. Emphasis on Technology Integration: The NEP recognizes the importance of integrating technology into education to enhance teaching and learning processes. By promoting the use of digital tools and resources, including AR, the NEP encourages schools and educational institutions to adopt innovative approaches to instruction and curriculum delivery.

2. Focus on Experiential Learning: Augmented reality offers immersive and experiential learning experiences that enable students to interact with digital content in real-world contexts. The NEP emphasizes the importance of experiential learning and hands-on activities to foster deeper understanding and retention of concepts. Augmented learning aligns with this objective by providing students with opportunities to explore, experiment, and engage actively in the learning process.

3. Personalized and Adaptive Learning: Augmented reality technologies can be

customized to meet the diverse learning needs and preferences of students. The NEP advocates for personalized and adaptive learning approaches that cater to individual differences in learning styles, abilities, and interests. Augmented learning platforms can adapt content, pace, and presentation to accommodate students' unique learning requirements, thereby promoting inclusive education practices.

4. Enhancement of Teacher Effectiveness: The NEP recognizes the pivotal role of teachers in facilitating student learning and development. Augmented learning tools can empower teachers to create dynamic and engaging learning experiences that captivate students' interest and promote active participation. By providing teachers with access to AR resources and training, the NEP can enhance their pedagogical skills and effectiveness in utilizing technology for instructional purposes.

5. Preparation for 21st-century Skills: In line with the NEP's focus on preparing students for the demands of the 21st century, augmented learning can equip learners with essential digital literacy, critical thinking, problem-solving, and collaboration skills. By incorporating AR experiences into the curriculum, the NEP can help students develop the competencies required to thrive in an increasingly technology-driven world.

6. Promotion of Innovation and Research: The NEP encourages research and innovation in education to drive continuous improvement and advancement. Augmented reality represents a cutting-edge technology with immense potential for transforming teaching and learning practices. By supporting research initiatives and pilot projects focused on augmented learning, the NEP can facilitate the development of evidence-based best practices and guidelines for its effective implementation.

Overall, the National Education Policy can play a vital role in promoting the use of augmented learning in education by fostering a conducive policy environment, providing

resources and support, and aligning educational goals with the opportunities offered by emerging technologies like augmented reality. Through strategic integration of AR into educational practices, the NEP can contribute to the enhancement of teaching quality, student engagement, and learning outcomes across diverse educational settings.

2. Background of the Problem

AR technology is classified into several technologies according to Milgram and Kishino (1994) into the reality-virtuality continuum, which consists of the real environment, augmented reality, augmented virtuality, and the virtual environment. On the other hand, according to Azuma (2001), AR technology is classified into four categories depending on the tracking method and the display, namely spatially aware, spatially enabled, spatially matched, and spatially oriented. The tracking method, in this case, is a method to monitor the position and orientation of the object one is mixing between real and virtual. While the display is a representation of virtual objects in real environments. Although both classifications are different, they are related to the notion of AR, which is a process for the result of combining three-dimensional virtual objects into the real environment in real time and lasting.

Augmented reality (AR) technology, defined as a system that fulfils three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects (Azuma, 1997), has been widely used in various applications and has gained attention in education, including in science education. However, implementing AR in education is not an easy task due to several constraints. To overcome these constraints, a comprehensive understanding of what AR is and the potential to implement it in science education is needed. This paper describes the current AR technologies and reviews the potential to implement them in science education, especially in secondary education.

3. Objectives of The Study

1. To explore the current technologies in augmented reality.
2. To study the potential applications of AR in science education in India using Literature Reviews.
3. To study and analyse 10 articles using Scoping Review Method.
4. To explores the current landscape of AR technologies, with a specific focus on DAQRI Elements 4D and Exploratorium AR, and their potential applications in secondary science education.
5. To study AR humanoid 4D app, and its potential for improving science education outcomes in Indian secondary schools.

4. Hypothesis of the Study

1. The hypothesis for this study is that augmented reality has significant potential applications to greatly enhance science education in secondary schools by providing interactive and immersive learning experiences.
2. The hypothesis for this study is that augmented reality in Science Education reviewed through literature shows significant potential applications to greatly enhance science education in secondary schools.
3. The hypothesis for this study is that AR technologies, with a specific focus on DAQRI Elements 4D and Exploratorium AR, have significant potential applications in secondary science education.
4. The hypothesis for this study is that AR humanoid 4D app have significant potential applications for improving science education outcomes in Indian secondary schools.

5. Definitions

5.1. Augmented Reality

Augmented reality technology has come a long way since it first entered the educational scene. There are many different definitions for augmented reality, but they all include the idea of using "computer generated information" in some way to change or enhance what we see. Augmented reality is different from virtual reality. In virtual reality, the user is completely immersed in an entirely artificial environment. Augmented reality has a much wider scope because it can be used to enhance the immediate surroundings in a number of different ways. For example, consider a student on a field trip to a historical site. With a tablet PC and an augmented reality application, the student could aim the tablet at a particular building and immediately receive historical information and pictures overlaying the current view. This kind of flexibility and freedom isn't as feasible with virtual reality technology.

5.2. DAQRI Elements 4D

It is a versatile augmented reality (AR) platform developed by DAQRI, a leading provider of AR solutions. This platform allows users to create and interact with augmented reality experiences that blend digital content with the physical world in real-time.

5.3. Exploratorium AR

It is an augmented reality (AR) platform developed by the Exploratorium, a museum of science, art, and human perception located in San Francisco, California. Exploratorium AR offers users the opportunity to engage with scientific phenomena and exhibits in an immersive and interactive way using augmented reality technology.

5.4. Humanoid 4D

It refers to a type of augmented reality (AR) experience that involves the integration of humanoid virtual characters or avatars into the user's physical environment. This technology typically utilizes AR applications or platforms to superimpose lifelike 3D models of human-like characters, known as "humanoids," onto the real world through the camera view of a mobile device or AR glasses.

5.5. Secondary Education

Secondary education in India typically refers to education for students aged 14 to 18 years, covering classes 9 to 12. According to the NEP, secondary education aims to provide students with a comprehensive and holistic education that builds on the foundational learning acquired in earlier stages. It emphasizes the development of critical thinking, problem-solving skills, and preparing students for further education, careers, and citizenship.

6. Review of Related Literature

A detailed study on the use of Augmented Reality in Science using the following sources of Related Literature:

6.1. Importance of Augmented Reality in Science Education

Augmented Reality (AR) holds significant importance in science education due to its ability to transform traditional teaching methods into immersive, interactive, and engaging learning experiences. Here are several key reasons why AR is valuable in science education:

1. **Enhanced Visualization**: AR allows students to visualize abstract scientific concepts in 3D, making them more tangible and easier to understand. By overlaying virtual

objects onto the real world, AR enables students to explore complex structures, such as molecules, cells, or astronomical phenomena, with depth and clarity.

2. **Interactivity and Engagement**: AR provides hands-on, interactive learning experiences that captivate students' attention and foster active engagement. Through AR applications, students can manipulate virtual objects, conduct virtual experiments, and observe dynamic processes in real-time, leading to deeper levels of comprehension and retention of scientific principles.
3. **Personalized Learning**: AR platforms can adapt to individual learning styles and paces, offering customized learning experiences tailored to students' needs and preferences. Teachers can use AR to provide targeted support, remediation, or enrichment activities, ensuring that each student receives a personalized learning journey aligned with their unique strengths and challenges.
4. **Real-World Contextualization**: AR contextualizes scientific concepts within real-world environments, enabling students to see how theory applies to practice. By overlaying virtual simulations onto physical surroundings, AR bridges the gap between abstract knowledge and everyday experiences, helping students make meaningful connections between science and their lives.
5. **Promotion of Inquiry-Based Learning**: AR encourages inquiry-based learning approaches, where students actively explore, question, and discover scientific phenomena. By providing access to interactive simulations, virtual laboratories, and augmented field trips, AR empowers students to pose hypotheses, design experiments, and draw conclusions through hands-on exploration and critical thinking.
6. **Collaborative Learning Opportunities**: AR fosters collaboration and teamwork among students, promoting peer-to-peer learning and knowledge sharing. Through collaborative AR projects, students can work together to solve problems, analyze data,

and communicate their findings, developing essential collaboration, communication, and teamwork skills essential for success in STEM fields.

7. **Preparation for Future Careers**: AR equips students with digital literacy skills and technological competencies relevant to the 21st-century workforce. By integrating AR technologies into science education, students gain exposure to cutting-edge tools used in industries such as healthcare, engineering, and research, preparing them for future careers in STEM fields where AR is increasingly prevalent.

Overall, the importance of Augmented Reality in science education lies in its capacity to revolutionize teaching and learning, making science more accessible, engaging, and relevant to students' lives. By harnessing the immersive and interactive nature of AR, educators can inspire curiosity, cultivate critical thinking skills, and empower students to become lifelong learners and active participants in the scientific community.

6.2. Overview of different Augmented Reality Technologies

Augmented Reality (AR) technology encompasses a variety of approaches and devices that overlay digital information onto the physical world to enhance user experiences. Here's an overview of some of the different types of AR technology.

1. **DAQRI Elements 4D**:
    - **Description**: DAQRI Elements 4D is an AR platform that allows users to create and interact with 4D digital content, combining 3D models with dynamic animations and interactive elements.
    - **Features**:
        - Creation Tools: Allows educators to create custom AR content, such as 3D models of scientific phenomena, molecular structures, or geological formations.

- Interactivity: Supports interactive elements like animations, simulations, and quizzes to engage students in hands-on learning experiences.
- Compatibility: Works with compatible AR-enabled devices like smartphones, tablets, or AR glasses.

- **Applications in Science Education**:
  - Visualizing Complex Concepts: Enables students to visualize abstract scientific concepts in 4D, making them more accessible and engaging.
  - Interactive Experiments: Facilitates virtual experiments and simulations, allowing students to explore scientific principles in a dynamic and interactive manner.
  - Custom Content Creation: Empowers educators to create personalized learning experiences tailored to specific curriculum objectives or learning goals.

2. **Exploratorium AR**:
   - **Description**: Exploratorium AR is an AR application developed by the Exploratorium museum, designed to provide interactive educational experiences in science, technology, engineering, and mathematics (STEM).
   - **Features**:
     - Curated Content: Offers a library of curated AR experiences covering various STEM topics, including physics, biology, astronomy, and environmental science.
     - Real-world Context: Integrates AR content with real-world environments, allowing students to explore scientific concepts in their natural context.

- Accessibility: Available for download on mobile devices, making it accessible to a wide audience of students and educators.

- **Applications in Science Education**:
  - Virtual Field Trips: Provides immersive virtual field trips to scientific landmarks, museums, or natural habitats, allowing students to explore diverse ecosystems and geological formations.
  - Interactive Demonstrations: Offers interactive demonstrations and simulations of scientific phenomena, enabling students to conduct virtual experiments and observe real-time outcomes.
  - Inquiry-based Learning: Supports inquiry-based learning approaches by encouraging students to ask questions, make observations, and draw conclusions through hands-on exploration.

3. **Humanoid 4D +**:
   - **Description**: Humanoid 4D+ is an AR educational tool that brings human anatomy to life through interactive 4D models of the human body.
   - **Features**:
     - Detailed Anatomy: Provides detailed 4D models of human anatomy, including skeletal, muscular, circulatory, and nervous systems.
     - Interactivity: Allows students to interact with virtual anatomy models, explore different layers, and identify individual structures.
     - Educational Content: Offers educational materials, quizzes, and explanations to deepen students' understanding of human biology and physiology.
   - **Applications in Science Education**:

- Anatomy Education: Enhances anatomy education by offering immersive and interactive experiences that enable students to explore the human body in unprecedented detail.
- Medical Training: Supports medical training and healthcare education by providing realistic simulations of anatomical structures and physiological processes.
- Cross-disciplinary Learning: Facilitates cross-disciplinary learning by integrating concepts from biology, health sciences, and medicine into science education curricula.

In summary, AR technologies like DAQRI Elements 4D, Exploratorium AR, and Humanoid 4D+ offer innovative solutions for enhancing science education by providing immersive, interactive, and personalized learning experiences. These tools empower students to visualize complex scientific concepts, conduct virtual experiments, and explore the wonders of the natural world in new and exciting ways, ultimately fostering curiosity, inquiry, and a deeper appreciation for science.

6.3. Review of Related Research

1. Faruk A., Mehmet Y.(2022) , had studied an examination of the effectiveness of problem-based learning method supported by augmented reality in science education.

In their study, the effect of PBL supported by AR on academic achievement, reflective thinking skills towards problem-solving, decision-making abilities, and the permanence levels of the 7th-grade students were researched.

The embedded design from mixed methods was used in the study, which had two experimental groups and one control group. For the Experiment-1, Experiment-2, and Control

Groups, respectively, PBL supported by AR, PBL alone, and the current teaching method were used. The sample consists of 92 students from the seventh grade.

In terms of academic achievement, reflective thinking skills towards problem-solving, and decision-making abilities, the Experiment-1 Group outperformed the Experiment-2 and Control Groups, and the Experiment-2 Group outperformed the Control Group. It has been discovered that PBL supported by AR is more effective than solely PBL and the currently used teaching method in terms of improving reflective thinking skills towards problem-solving and decision-making abilities, as well as the persistence of academic achievement in a science course.

2. Hidayat R.,Vardat Y.(2023) , had studied a systematic review of Augmented Reality in Science, Technology, Engineering and Mathematics education. The primary objective of their study was to review current studies in which Augmented Reality learning was used to assist Science, Technology, Engineering and Mathematics education. This study was guided by the processes of identification, screening, eligibility, included and data analysis on three search engines which were ERIC, ScienceDirect and Scopus. In reporting their research, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis protocol was followed which identified 42 related articles. Their findings revealed that three popular types of Augmented Reality design were being utilized in Science, Technology, Engineering and Mathematics learning including marker-less Augmented Reality, marker-based Augmented Reality and projection-based Augmented Reality. The SR outputs also indicated that most scholars employed cameras and object markers as technological modalities to support Science, Technology, Engineering and Mathematics education. Finally, 3D and animated elements were widely used augmented components in Science, Technology, Engineering and

Mathematics education. One of the significant implications was that comprehending these distinctions could help in the choice of the appropriate Augmented Reality variant for a specific use circumstance and enable the creation of successful Augmented Reality experiences that fulfil predetermined goals.

3. Yilmaz.O , had studied Augmented Reality in Science Education: An Application in Higher Education. Effective usage of augmented reality(AR) depends on good integration into the learning environment. Based on a qualitative research approach, their study investigates the effects of using AR technologies in science education to support the effective use of AR. Students' experiences of AR were gathered using a prepared questionnaire form. Within the scope of science education, AR was used in a university-level chemistry course. Using theme analysis, descriptive themes were created by analyzing the content of completed questionnaires in written texts. Descriptive expressions obtained from the written text were determined by free coding. These codes were then matched with appropriate themes and illustrated in the form of branched trees. The study results demonstrated that AR is an optimal tool for teaching abstract subjects that do not feature direct observation and examination in science education. Students also have positive opinions about the use of AR in other courses in science education. Another important result from this study revealed that AR software interfaces require improvements to be suitable as teaching material. In addition, several recommendations have been presented for the better integration of AR into the learning environment.

4. Masalimova A., ErdyneevaK., KryukovaN., Khlusyanov O., had studied Bibliometric analysis of augmented reality in education and social science. Augmented reality (AR) overlays virtual elements on real-time images. Because to its ubiquitous use on desktop

computers and handheld devices, it has become a major study topic. AR provides benefits like engagement, motivation, and learning result, but drawbacks like the technology tool and application and pedagogical challenges. After 2015, global Google searches for AR increased. Their study analyzed "AR" literature released after 2015. Exclusion and inclusion criteria are studies were divided into social sciences and education and published in English. Research should be published during 2015-2022. 3,823 studies were analyzed. AR publications will increase after 2020. Annual citations averaged 2.49. Computer & Education leads the top ten journals in citations. National Taiwan Normal University and Beijing Normal University have the most publications when ordered by writers' institutions. China leads global publications, whereas the US leads overall publications. China led in citations, followed by the US. Macedonia led the average number of article citations, followed by Israel. The strategic map shows the center and density of key issues. "Student learning," "AR applications," and "AR technology" are linked and vital terms. Based on the results of the bibliometric study, researchers who wish to work on AR may emphasize theme-based learning studies and AR. Researchers that are considering conducting bibliometric analysis on AR are urged to conduct research utilizing many databases.

5. Kalemkuş J., Kalemkuş F.(2021), had studied Effect of the use of augmented reality applications on academic achievement of student in science education: meta analysis review.

They aimed to review the effect of the use of augmented reality applications on the academic achievement of students in science education in this study. In line with this aim, the experimental researches reviewing the effect of use of augmented reality applications within the scope of science course on student achievement were evaluated with meta-analysis method. The studies included into this research were accessed from ERIC, Google Scholar, Science Direct, Springer Link, Taylor & Francis, Web of Science databases in line with

certain criteria. In order to reach these studies from databases, the following key words were used; "'augmented reality' & 'achievement'" and "'augmented reality' & 'achievement & science'". Funnel plot, Orwin's Fail-Safe N and Egger tests were used for detecting the publication bias and it was determined that there is no publication bias. At the end of the meta-analysis, it was determined that the effect of the use of the augmented reality applications on the student achievement in the science course is moderate (d = 0,643) in favor of the experimental group. Thus, it was presented that the use of the augmented reality applications affects the student achievement positively in the science course.

6. Nielsen B., Brandt H., Swensen H.,had studied, Danish University Colleges Augmented Reality in science education – affordances for student learning .Their paper presents findings addressing the issue of AR for educational purposes based on a sequential survey distributed to 35 expert science teachers, ICT designers and science education researchers from four countries. There was consensus among experts in relation to a focus on 'learning before technology', and they in particular supplemented affordances identified in literature with perspectives related to interactivity, a creator perspective and inquiry based science. Expert reflections were condensed into innovative dimensions in a framework with nine continua. The framework can be used to illustrate how, and to what extent, an innovative educational perspective, such as that focusing on engaging learners in creating and/or inquiring can be addressed in a particular AR design, and is in the paper exemplified for use in both analysis of existing educational AR and in design of new second-generation AR.

7. Booyoesen T., had studied, Exploring the Impact of Augmented Reality on Student Engagement and Learning Outcomes in Science Education. Their study explores the transformative possibilities of augmented reality (AR) in the field of scientific education,

within the context of a technologically sophisticated society. In this research, we examine the impact of augmented reality (AR) on student engagement and learning outcomes via the implementation of a quasi-experimental design including both control and experimental groups. The examination of pre-test and post-test data reveals a statistically significant enhancement in learning outcomes among participants in the experimental group, hence indicating the efficacy of augmented reality (AR) in enhancing students' understanding of scientific concepts. The examination of engagement behaviors via observation demonstrates the role of augmented reality (AR) in facilitating collaborative learning experiences and maintaining attention, hence leading to enhanced student engagement. The results of this study align with other research that emphasizes the capacity of augmented reality (AR) to provide interactive and captivating educational experiences while enhancing comprehension. This research emphasizes the potential impact of augmented reality (AR) on scientific education, as it offers dynamic and immersive learning environments that effectively engage students and facilitate meaningful learning outcomes. While limitations necessitate additional investigation, the results of this study highlight AR's ability to transform the educational environment and improve the quality of science instruction.

8. Schmidthaler E., had studied, Effects of Mobile Augmented Reality Apps in Science Education on Austrian Secondary School Students' Health.The implementation of Mobile Augmented Reality (mAR) apps in Austrian secondary science education has demonstrated enhanced learning outcomes, increased engagement, and improved spatial understanding. However, this practice presents challenges, including infrastructure constraints, addictive behavior concerns, and potential health impacts on the students. This mini-review investigates the effects of mAR apps on the health of students, addressing issues like addictive usage, motion sickness, and psychological implications. It highlights the importance of a balanced

approach, suggesting strategies to mitigate risks and proposing future research to assess long-term (m) AR implications on well-being and academic performance. Furthermore, it emphasizes the need for guidelines to regulate mARapp usage in education and advocates for exploring alternative teaching methods to minimize excessive screen time and potential addiction.

9. Mbonye V.. Ebrahim R, had studied Integrating Augmented Reality in Science Education in South Africa: Applications in the Mancosa iTEACHlab.

Integrating augmented reality (AR) in education merges the physical and virtual worlds to exhibit multi-dimensional content that would be difficult to display in a traditional classroom setting. Employing augmented reality in science education results in favourable outcomes since it enables learners to acquire and comprehend abstract science concepts. To achieve these positive outcomes, augmented reality must be successfully integrated into science lessons. However, there is limited material on how augmented reality can be implemented into science education in South Africa. Case studies enable individuals to learn from their experiences and to discover approaches that shape and accelerate progress toward resolving challenges. The purpose of their case study is to share experiences from augmented reality installations at the Mancosa school of education's iTEACHlab. Also, the article presents an overview of augmented reality (AR) and its educational applications in South Africa. The paper adopts a document analysis technique to collect and analyse the data. Thus, it provides crucial information on how educational institutions might employ augmented reality into science education.

10. Chu-Yang Chang, Hsu-Chan Kuo ,Zhengyi Du, had studied, The role of digital literacy in augmented, virtual, and mixed reality in popular science education: a review study and an

educational framework development. Their study aims to bridge the gap between extended reality (XR) and digital literacy (DL) in popular science education and further develop a DL–XR framework. XR includes augmented, virtual, and mixed reality (AR, VR, and MR), which has received increased attention and has been used for educational purposes in recent years. However, the studies of XR in popular science education and its impact on students are scant. It is also challenging to find studies entailing XR and DL in education. This study not only offers an overview of the status quo of XR education but also is the first research presenting a referential framework that systematically integrates the many dimensions of XR and DL for future research and educational practices. XR has been extensively used in museums, benefiting users with immersive, authentic, hands-on, and interactive experiences. In the DL–XR framework, based on the variations of "individual-group" and "passive consumption-active creation", eight dimensions of DL linked to XR are proposed, including "access and understanding", "evaluation", "ethics and well-being", "interaction", "collaboration", "creation", "problem-solving", and "civic engagement and responsibility". In the nurturing of DL, evidence revealed that XR is mostly used for learners to access knowledge/information and interact with virtual items; nonetheless, its applications for active creation, problem-solving, and collaboration are seldom prioritised. This study further proposes integrating project-based learning into XR pedagogical practices, which can maximise its impact on learning and empower the learners to achieve advanced levels of DL.

7. Research Methodology

The goal of this review is to identify the potential use of AR in different fields of education. The keyword used in the search of the literature was the phrase "Augmented Reality". There were 50 hits from the keyword search,of which ten were selected after taking into account certain criteria. Firstly, only studies conducted from 2007 to 2023 were selected. This is

because the AR technologies began to emerge in 2007. Secondly, the studies must represent different fields in order to give examples of how AR has been used in a range of areas. Lastly, the studies must highlight the purpose and the features of the AR technology that had been used. The search of the literature was conducted using Litmaps (https://app.litmaps.com/) which is the online platform for literature. Litmaps could refer to tools or platforms designed for literature mapping.

The results are presented in Table 2.

Table.2. Meta-Analysis of Research on the Use of AR in different Fields of Education

Author/s	Field	Purpose of AR Use	AR Features Used
Chang et al. (2011)	Medical education (surgical training)	To provide training and to plan and guide surgical procedures	AR image-guided therapy.
Yeom (2011)	Medical education (anatomy)	To teach and test anatomy knowledge (of the abdomen in particular)	Interactive 3D anatomy pictures and haptic feedback.
Hedegaard et al. (2007)	Medical education using the electrocardiogram (ECG/EKG) AR system (called the EKGAR system)	To extend medical students' spatial awareness in relation to specific myocardial diseases by enabling users to navigate through and slice open 3D representations of a patient's heart	Vision-based 3D tracking technologies and interactive features
Singal et al. (2012)	Chemistry education	To provide an efficient way to represent and interact with molecules, leading to a better understanding of the spatial relation between molecules	AR technology for exhibiting the models
Cerqueira & Kirner (2012)	Mathematics	To teach geometry through the use of 3D geometrical concepts	Head-mounted display and personal interaction panel
Mathison & Gabriel (2012)	Biology (School in the Park project)	To teach participants that habitats are connected like links in a chain (food chain)	AR experience

Coffin et al. (2008)	Physics	To overlay graphics on top of the physical props to visualize these forces (speed, velocity, acceleration, pressure, friction, energy changes) invisible to the human eye	Augmented video, videoconferencing, tracked physical props (e.g. toy cars)
Nechypurenko(2018)	Chemistry	Solving such problems as: the generalization and analysis of the scientific researches results on the use of the augmented reality in the chemistry education, the characteristics of the modern AR–tools in the chemistry education and the forecasting of some possible areas of the development and improvement of the Ukrainian tools of the augmented reality in the chemistry education.	3 D Model using AR
Carreon (2020)	K12 Environment	The results of the review reveal that studies use varying defining characteristics of AR which leads to varying levels of applications for all students in instructional settings.	AR through ipad,iphone
Mbonye V.. Ebrahim R(2022)	Science Education	Establishment of AR in school	Iteachlab

The summary provided highlights the widespread adoption of Augmented Reality (AR) technology across various fields for teaching and learning purposes. Research studies consistently show positive feedback from participants regarding the effectiveness of AR

systems in education. Consequently, there is a call for further research into the integration of AR technology in teaching and learning due to its clear benefits for both students and teachers.

AR technology has demonstrated its potential to enhance the teaching of subjects that involve visualization compared to traditional methods alone. By overlaying digital content onto the physical world, AR provides immersive and interactive learning experiences that engage students and facilitate comprehension of complex concepts. Additionally, AR offers opportunities for personalized learning, hands-on exploration, and collaborative problem-solving, making it a valuable tool for educators seeking to enhance their teaching practices.

Overall, the conclusion emphasizes the importance of continued research and innovation in leveraging AR technology to improve educational outcomes. By exploring new applications, refining existing methodologies, and addressing challenges, educators can unlock the full potential of AR as a transformative tool for teaching and learning in diverse academic disciplines.

8. Limitations for AR and Suggestions for Further Research

While Augmented Reality (AR) holds significant potential for enhancing teaching and learning, it is important to acknowledge some limitations and areas for further research:

8.1. Limitations

1. **Technical Challenges**: AR technology may face technical limitations such as limited device compatibility, connectivity issues, and hardware constraints. These challenges can impact the usability and accessibility of AR applications, particularly in educational settings with diverse technological infrastructures.

2. **Cost and Accessibility**: The cost of AR hardware and software can be prohibitive for some educational institutions, limiting access to AR experiences for students and teachers. Additionally, disparities in access to devices and internet connectivity may exacerbate inequalities in education.
3. **Content Quality and Relevance**: The quality and relevance of AR content can vary widely, impacting its effectiveness for teaching and learning. Poorly designed or inaccurate AR experiences may fail to engage students or convey educational concepts effectively.
4. **Pedagogical Integration**: Integrating AR technology into existing educational practices requires careful planning and pedagogical considerations. Teachers may lack the necessary training, resources, or support to effectively incorporate AR into their lessons, leading to underutilization or ineffective implementation.

8.2. Suggestions for Further Research

1. **User Experience and Interaction Design**: Further research is needed to explore the user experience and interaction design principles that optimize AR applications for educational contexts. This includes investigating factors such as usability, engagement, and accessibility to ensure that AR experiences are intuitive and effective for diverse learners.
2. **Learning Outcomes and Assessment**: Future studies should focus on evaluating the impact of AR technology on learning outcomes, retention of knowledge, and student engagement. Longitudinal studies and comparative research can provide insights into the effectiveness of AR-enhanced teaching methods compared to traditional approaches.
3. **Teacher Training and Professional Development**: Research should examine strategies for training and supporting educators in integrating AR technology into their

teaching practices. This includes developing curriculum materials, providing technical support, and fostering pedagogical competencies related to AR-based instruction.

4. **Content Creation and Cu-ration**: Studies should investigate methods for creating high-quality, curriculum-aligned AR content that addresses diverse learning objectives and instructional needs. Collaborative approaches involving educators, instructional designers, and content developers can ensure that AR experiences are relevant, engaging, and pedagogically sound.
5. **Equity and Inclusion**: Research should explore strategies for addressing equity and inclusion challenges in AR-enabled education, particularly regarding access, affordability, and representation. This includes designing inclusive AR experiences that accommodate diverse learners and promoting equitable access to AR technology in educational settings.

By addressing these limitations and advancing research in these areas, educators and researchers can maximize the potential of AR technology to enrich teaching and learning experiences, promote student engagement and achievement, and foster innovation in education.

9. Conclusion

Augmented reality has significant potential applications to greatly enhance science education in secondary schools by providing interactive and immersive learning experiences.

Augmented reality in Science Education reviewed through literature shows significant potential applications to greatly enhance science education in secondary schools.

AR technologies, with a specific focus on DAQRI Elements 4D and Exploratorium AR, have significant potential applications in secondary science education.

AR humanoid 4D app have significant potential applications for improving science education outcomes in Indian secondary schools.

The review presented underscores the promising potential of Augmented Reality (AR) technology in education, highlighting its ability to engage students, enhance visualization skills, and facilitate understanding of complex concepts. AR features are shown to support teachers in delivering effective explanations and fostering student comprehension, leading to positive feedback and interest from participants and students alike.

Despite the notable benefits of AR in education, the review acknowledges that there are still some limitations, particularly related to technical issues. However, these limitations are viewed as surmountable obstacles that can be addressed through ongoing research and development efforts. As AR technology continues to evolve and improve, it is expected that these technical challenges will diminish, paving the way for wider adoption and integration of AR across various educational disciplines.

The review suggests that as research on the integration of AR in education progresses, the full potential of AR technologies can be realized, leading to more efficient teaching and learning processes. With continued exploration and refinement, AR has the capacity to revolutionize education by offering innovative ways to engage learners, personalize instruction, and promote active participation in the learning process.

Overall, the review emphasizes the transformative impact that AR technology can have on education when its potential is fully harnessed. By addressing technical limitations and capitalizing on the benefits of AR features, educators can unlock new possibilities for

enhancing student learning experiences and achieving educational goals across diverse fields of study.

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