



Barriers and Opportunities in the Application of Augmented Reality-Based Learning Media in Elementary Schools: A Systematic Review of Educational Practices

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Abstract

The rapid advancement of educational technology has created new opportunities for integrating innovative tools such as Augmented Reality (AR) into elementary education. This systematic literature review examines the barriers and opportunities in the implementation of AR-based learning media in elementary schools. Following the PRISMA protocol, 35 peer-reviewed articles published between 2015 and 2024 were analyzed to identify challenges related to technology, infrastructure, pedagogy, and teacher competence. The findings reveal that major barriers include limited hardware and software availability, inadequate technical infrastructure, insufficient teacher training, and difficulties in curriculum integration. Conversely, AR presents substantial opportunities to enhance student engagement, support project-based learning, and foster 21st-century skills development. This study contributes scientifically by providing a comprehensive and up-to-date synthesis that specifically focuses on elementary education contexts, an area that has received limited systematic attention in prior research. Furthermore, it offers an integrative analytical framework that maps barriers and opportunities across multiple dimensions, thereby extending existing AR adoption literature beyond benefit-oriented discussions. The results also generate practical implications for policymakers, educators, and technology developers by identifying strategic pathways to support sustainable and inclusive AR implementation in primary education. This review thus advances both theoretical understanding and evidence-based practice related to AR integration in elementary schools.

Keywords: Augmented Reality; Educational Barriers; Educational Opportunities; Elementary Education; Learning Media;

Abstrak

Perkembangan pesat teknologi pendidikan telah membuka peluang baru untuk mengintegrasikan alat-alat inovatif seperti Augmented Reality (AR) ke dalam pendidikan dasar. Tinjauan literatur sistematis ini menganalisis hambatan dan peluang dalam implementasi media pembelajaran berbasis AR di sekolah dasar. Mengikuti protokol PRISMA, 35 artikel yang telah direview oleh rekan sejawat yang diterbitkan antara tahun 2015 dan 2024 dianalisis untuk mengidentifikasi tantangan terkait teknologi, infrastruktur, pedagogi, dan kompetensi guru. Temuan menunjukkan bahwa hambatan utama meliputi ketersediaan perangkat keras dan perangkat lunak yang terbatas, infrastruktur teknis yang tidak memadai, pelatihan guru yang tidak memadai, dan kesulitan dalam integrasi kurikulum. Di sisi lain, AR menawarkan peluang signifikan untuk meningkatkan keterlibatan siswa, mendukung pembelajaran berbasis proyek, dan mengembangkan keterampilan abad ke-21. Studi ini memberikan kontribusi ilmiah dengan menyajikan sintesis komprehensif dan terkini yang secara khusus berfokus pada konteks pendidikan dasar, bidang yang belum mendapat perhatian sistematis yang memadai dalam penelitian sebelumnya. Selain itu, studi

ini menawarkan kerangka analitis integratif yang memetakan hambatan dan peluang di berbagai dimensi, sehingga memperluas literatur adopsi AR melampaui pembahasan yang berorientasi pada manfaat. Hasil penelitian ini juga memiliki implikasi praktis bagi pembuat kebijakan, pendidik, dan pengembang teknologi dengan mengidentifikasi jalur strategis untuk mendukung implementasi AR yang berkelanjutan dan inklusif.

Kata kunci: *Augmented Reality; Media Pembelajaran; Pendidikan Dasar; Hambatan Pendidikan; Peluang Pendidikan*

INTRODUCTION

The development of technology in the world of education has opened up great opportunities for applying more interactive and effective learning innovations (Brizar & Kažović, 2023). One of the technologies that is gaining more attention is Augmented Reality (Rötkönen et al., 2022). As a technology that combines the real world with virtual elements, Augmented Reality has great potential to revolutionize the way students learn (Abadia et al., 2024), especially at the elementary school level (Ventes et al., 2023). In the context of basic education, where learning often focuses on exploring and understanding basic concepts, Augmented Reality offers an immersive and engaging learning experience (Maulida, 2024). With Augmented Reality, students can witness three-dimensional simulations of objects or phenomena that are difficult to explain directly (Pasalidou et al., 2023).

The use of Augmented Reality not only enhances student engagement through engaging visualizations (Aldeeb et al., 2024), but it is also able to enriches the learning experience for elementary school students (Nurcahyani & Sudarmilah, 2023). This technology allows students to interact with learning materials directly (Topalska, 2024), manipulate digital objects, and explore abstract concepts that were previously difficult to grasp (Baran et al., 2020). In addition, Augmented Reality is also considered effective in supporting different learning styles (Yildirim & Kececi, 2024), such as visual, kinesthetic, and auditory, making it an inclusive tool for various types of learning needs (Levyta et al., 2023).

However, despite its great potential, the application of Augmented Reality in primary schools still faces obstacles and challenges both in terms of technical, financial, and pedagogical (Gong & Marghitu, 2024). Technical barriers include limitations in infrastructure, such as hardware and software that support Augmented Reality (Özçakır & Çakıroğlu, 2022). Many schools, especially in underdeveloped areas, do not have access to adequate technology (Peikos, 2024). On the other hand, financial problems include high implementation costs, ranging from device purchases, development of relevant Augmented Reality content, to teacher training (Kar et al., 2021). Pedagogically, there is a challenge in ensuring that teachers have the competence to integrate Augmented Reality into the curriculum in an effective and meaningful way (Zulkifli et al., 2021).

Nonetheless, these obstacles can be overcome strategically (Cygnet & Sivakumar, 2024). The provision of technology assistance through partnerships with the private sector, the development of low-cost Augmented Reality applications, and the implementation of community-based learning models can be effective solutions (Muršić, 2020). In addition, intensive training and sustainability programs for teachers will allow for a smoother

integration of Augmented Reality into the classroom (Benvenuti et al., 2023). A great opportunity from the application of Augmented Reality is the ability to create a more inclusive and adaptive learning environment (Syskowski et al., 2024), allowing students to learn at their own pace and style (Seiari et al., 2023). The technology could also pave the way for project-based learning, encouraging 21st-century skills such as collaboration, creativity, and problem-solving (Deha et al., 2023).

Research related to the application of Augmented Reality in Education Most existing studies focus on secondary and higher education (Algethami, 2023) (de Clara, 2023). In addition, previous research has often only explored the benefits of this technology in general without discussing in detail the obstacles faced in its implementation (Stojšić et al., 2022). Furthermore, although there is literature that evaluates the application of Augmented Reality in Education (Colamatteo et al., 2024), it still does not systematically examine the practices that have been carried out in the field (Majid et al., 2022). For this reason, this article offers a systematic review approach to real practice in various basic education contexts in several countries that is still rarely practiced. Research like this is needed to identify key bottlenecks, successful strategies, and long-term opportunities that can be optimized. This literature study is relevant in a global context, where the gap in access to educational technology is still a major issue. By mapping out obstacles and opportunities, this article contributes to efforts to create a more inclusive, innovative, and adaptive education to the needs of students in the 21st century. Without efforts to overcome these barriers, students risk missing out on the opportunity to learn more effectively in the modern era.

To answer that, the purpose of the study: to analyze the obstacles to the implementation of Augmented Reality in elementary schools and opportunities that can be leveraged to optimize the use of Augmented Reality in elementary schools.

METHODS

The Systematic Literature Review is conducted to provide a reliable assessment of empirical evidence on barriers and opportunities to the application of Augmented Reality in elementary schools. Follow the PRISMA procedure (Liberati et al., 2009) which will be described in Figure 1. A PRISMA-based systematic literature review was selected to ensure a transparent, rigorous, and replicable synthesis of existing studies, enabling a comprehensive mapping of evidence on the implementation of Augmented Reality in elementary education. This approach allows for the minimization of selection bias while providing a structured, methodologically sound analysis of both barriers and opportunities across diverse educational contexts.

Search criteria are set based on research objectives to determine which articles to include or exclude from the analysis. This study uses search keywords (augmented AND reality AND in AND education OR barriers AND to AND augmented AND reality AND implementation OR opportunities AND for AND augmented AND reality AND in AND schools OR elementary OR

primary AND education AND technology). Literature eligibility is tied to those published in English from 2015 to 2024.

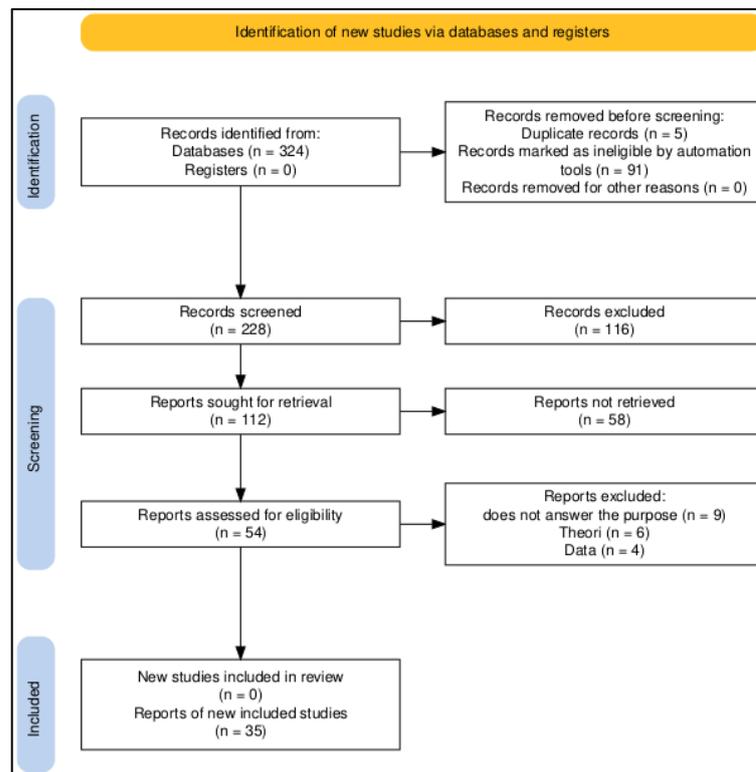


Figure 1. SLR Stage Flow Chart (Haddaway et al., 2022)

The database used in this article is a database from Scopus. A search of the Scopus database yielded 324 articles, including those identified by title, abstract, or keyword. The collected articles were checked for duplicates and articles without full text, totaling 96. The full text of 228 was excluded, as many as 116, because it did not match the title, and other articles were not taken by 58 because the research was not in elementary school. The collected articles are further assessed for eligibility against the criteria presented in Table 1.

Literature that did not meet the eligibility criteria was excluded and resulting in 35 articles being used for further analysis. Literature is read, coded, and checked for consistency. Each publication is further categorized based on methodology and the country in which the first author's institution is located. Research methods include qualitative, quantitative, and mixed methods, as well as research and development. The collected articles are synthesized to answer the objectives in this article.

Table 1. The article includes and excludes criteria

Aspect	Inclusion Criteria	Operational Indicators (Inclusion)	Exclusion Criteria	Operational Indicators (Exclusion)
Research Focus	The article examines the use of Augmented Reality in educational settings	Explicit discussion of AR as a learning medium, tool, or instructional strategy	The article does not focus on Augmented Reality	AR is only mentioned marginally or used as a

Aspect	Inclusion Criteria	Operational Indicators (Inclusion)	Exclusion Criteria	Operational Indicators (Exclusion)
Educational Level	The study is conducted in elementary/primary school contexts	Participants are elementary/primary school students or teachers; learning content aligned with basic education	The study focuses on secondary, higher, or vocational education	secondary example Participants are high school, university students, or adult learners
Research Objectives	The article addresses barriers, challenges, opportunities, or implementation aspects of AR	Clear identification of obstacles, enabling factors, or implementation conditions	The article only reports learning outcomes without implementation discussion	Focus solely on achievement scores, motivation, or usability without contextual analysis
Methodological Type	Empirical research or systematic review studies	Qualitative, quantitative, mixed-methods, R&D, or SLR with data-based findings	Conceptual papers or opinion-based articles	No data collection, analysis, or empirical validation
Data Availability	The article provides sufficient methodological and result details	Clear description of methods, instruments, participants, and findings	Insufficient or unclear data reporting	Missing methodology, incomplete results, or inaccessible full text
Publication Type	Peer-reviewed journal articles	Indexed or reputable academic journals	Non-peer-reviewed sources	Conference abstracts only, editorials, book reviews
Language	Published in English	Full text available in English	Published in other languages	No English version available
Publication Year	Published between 2015–2024	Publication date falls within the defined time span	Published outside the selected range	Publication year before 2015

RESULTS AND DISCUSSION

Result

Obstacles in the Application of Augmented Reality in Elementary Schools

In 35 studies examining the application of Augmented Reality technology in primary schools, there were several major obstacles identified based on literature studies. These obstacles can be grouped into several important aspects, namely technology, pedagogy, infrastructure, and teacher competence (Juan & Dewitt, 2024). Augmented Reality technology requires compatible hardware and software, which is often a challenge at the elementary school level (Silva et al., 2017). Obstacles that often arise include the limitations of devices such as tablets or smartphones with adequate specifications (Sangodiah et al., 2023) (Lauer et al., 2021) (Syskowski et al., 2024) as well as the compatibility of Augmented Reality software with the operating system used (Grinshkun et al., 2021) (Peikos, 2024). In addition, the lack of technical support to deal with technical problems is also a significant obstacle (Filonenko et al., 2023) (Antoniou et al., 2018) [38].

The availability of infrastructure is the foundation in the application of Augmented Reality technology (Marín et al., 2022). Some primary schools face problems such as limited internet access, lack of wireless network (Stojšić et al., 2022) (Kulkarni & Harne, 2024) (Topalska, 2024) (Khilya, 2023) as well as a lack of classrooms designed to support the integration of advanced technology. These barriers are even greater in rural or remote areas, where technological infrastructure is inadequate (Flores-Bascuñana et al., 2020) (Kysela & Štorková, 2015). In the context of learning, the integration of Augmented Reality requires curriculum adaptations that support the use of this technology (J. Li et al., 2017) (Efstathiou et al., 2018) (de Moraes Rossetto et al., 2023). However, many schools face obstacles in aligning the traditional curriculum with Augmented Reality-based learning methods (Wen et al., 2023) (Stepanyuk et al., 2024).

These pedagogical challenges include difficulties in designing learning content that suits the needs of students, as well as a lack of empirical evidence regarding the effectiveness of Augmented Reality in improving learning outcomes (Fikri, 2025). Teachers play a key role in the successful implementation of Augmented Reality in the classroom (Stalheim & Somby, 2024) (Lazou & Tsinakos, 2023) (Costa et al., 2021). However, many teachers feel less confident or do not have enough skills to use this technology effectively (Maulida, 2024). Other obstacles are the lack of professional training focused on the application of Augmented Reality in learning (Gill et al., 2024) (Trory et al., 2018) as well as the limited time for teachers to learn new technologies (Herwin et al., 2023) (Jhuang et al., 2024) (Mones, 2017).

The following are the results of the analysis of obstacles obtained from the application of augmented reality-based learning media:

Table 2. Obstacles to the Implementation of Augmented Reality Learning Media in Elementary Schools

No	Aspects	Acquired Indicators	Articles Mentioning Barriers
1	Technology	Hardware and software limitations	(Silva et al., 2017); (Sangodiah et al., 2023); (Lauer et al., 2021); (Syskowski et al., 2024)
		Device compatibility issues	(Grinshkun et al., 2021); (Peikos, 2024)
		Lack of technical support	(Filonenko et al., 2023); (Antoniou et al., 2018); (Jhuang et al., 2024)
2	Infrastructure	Limited internet access	(Marín et al., 2022); (Costa et al., 2021); (Joo-Nagata et al., 2017)
		Lack of wireless network facilities	(Stojšić et al., 2022); (Kulkarni & Harne, 2024); (Topalska, 2024); (Khilya, 2023)
		Classrooms don't support technology integration	(Flores-Bascuñana et al., 2020); (Kysela & Štorková, 2015)
3	Pedagogy	Difficulties in curriculum adaptation	(J. Li et al., 2017); (Efstathiou et al., 2018); (de Moraes Rossetto et al., 2023)
		Challenges of designing Augmented Reality-based learning content	(Wen et al., 2023); (Stepanyuk et al., 2024)
		Lack of evidence of the effectiveness of Augmented Reality in learning	(Maulida, 2024)
4	Teacher Competence	Limited teacher skills	(Stalheim & Somby, 2024); (Lazou & Tsinakos, 2023); (Costa et al., 2018)
		Lack of professional training	(Gill et al., 2024); (Trory et al., 2018)
		Limited time to learn new technologies	(Herwin et al., 2023); (Jhuang et al., 2024); (Mones, 2017)

Opportunities in the Application of Augmented Reality in Elementary Schools

Based on a literature review of 35 articles on the application of Augmented Reality technology in elementary schools, several opportunities can be used to increase learning effectiveness. In the context of elementary schools, this technology allows teachers to visually and dynamically convey complex learning materials (Stalheim & Somby, 2024) making them easier for students to understand (J. Li et al., 2017) Additionally, Augmented Reality supports project-based learning and collaborative approaches (Marín et al., 2022) which encourages the development of 21st-century (Lazou & Tsinakos, 2023) (de Moraes Rossetto et al., 2023) such as problem-solving, creativity, and critical thinking (Costa et al., 2018) Augmented Reality technology continues to evolve at a rapid pace, presenting opportunities to access more

affordable and user-friendly devices and applications (Wahyuni et al., 2024) These technological innovations also allow the integration of Augmented Reality with devices already commonly used in elementary schools, such as tablets and smartphones (Jhuang et al., 2024) In addition, the increasing number of educational Augmented Reality applications available in the market makes it easy for teachers to adopt this technology without the need to develop special software. Although infrastructure challenges remain, increased global internet access and government investment in educational technology open up opportunities for broader implementation of Augmented Reality (Trory et al., 2018)

Technology assistance programs for schools, especially in remote areas, are the main supporters to ensure that the necessary infrastructure is available (Lazou & Tsinakos, 2023) In addition, the advent of 5G network technology is accelerating internet connections, which support real-time Augmented Reality applications (Kulkarni & Harne, 2024) One of the main advantages of Augmented Reality is its ability to increase student engagement and motivation. Augmented Reality allows students to learn through hands-on exploration (Flores-Bascuñana et al., 2020) (de Moraes Rossetto et al., 2023) such as exploring 3D objects, science simulations (Lauer et al., 2021) or virtual visits to historical sites (Stalheim & Somby, 2024) This not only increases the appeal of learning (Costa et al., 2021) but also broadens students (Arshad et al., 2023) That may be limited by their real-world experiences (Gill et al., 2024).

Table 3. Opportunities in the Application of Augmented Reality in Elementary Schools

No	Aspects	Indicator	Articles Mentioning Opportunities
1	Pedagogy	More interactive and immersive learning	(Stalheim & Somby, 2024); (J. Li et al., 2017)
		Supports a project-based approach and collaboration	(Marín et al., 2022); (Antoniou et al., 2018); (Flores-Bascuñana et al., 2020); (Danaei et al., 2020)
		21 st century skill development	(Lazou & Tsinakos, 2023); (Stalheim & Somby, 2024); (de Moraes Rossetto et al., 2023); (Wen et al., 2023)
2	Technology	Augmented Reality devices that are getting more affordable	(Syskowski et al., 2024)
		An easy-to-access educational app	(Kulkarni & Harne, 2024)
		Integration with common devices such as smartphones	(Jhuang et al., 2024); (Sangodiah et al., 2023)
3	Infrastructure	Improving global internet access	(Khilya, 2023); (Trory et al., 2018)
		Government investment in educational technology	(Stepanyuk et al., 2024)

No	Aspects	Indicator	Articles Mentioning Opportunities
		5G network technology for real-time applications	(Kulkarni & Harne, 2024)
4	Student Experience	Hands-on, exploratory-based learning	(Flores-Bascuñana et al., 2020); (de Moraes Rossetto et al., 2023)
		Interactive simulations for complex topics	(Lauer et al., 2021); (Stalheim & Somby, 2024)
		Increased student motivation and engagement	(Costa et al., 2021); (Arshad et al., 2023); (Gill et al., 2024)

Discussion

Obstacles in applying Augmented Reality technology in primary schools indicate the need for special attention to aspects of technology, infrastructure, pedagogy, and teacher competence. To overcome various obstacles in the implementation of Augmented Reality in elementary schools, a comprehensive and strategic solution is needed (Maulida, 2024) One of the key steps is to increase access to hardware and software that supports Augmented Reality technology (Vidak et al., 2024) This includes the provision of devices such as tablets, smartphones, or Augmented Reality glasses with adequate specifications (Kuanbayeva et al., 2024) as well as apps that are easy for teachers and students to use (Kon Joon Bhang, 2023) In addition, the technological infrastructure must be improved, especially in terms of stable internet connections, supporting local networks, and other supporting devices (Chen et al., 2024)

Continuous training for teachers is also key, as they play an important role in integrating Augmented Reality into the learning process (Goi, 2024) This training must include how to use technology technically, Augmented Reality-based learning design, and evaluation of its effectiveness in improving student engagement and learning outcomes (Mones, 2017) Furthermore, in-depth empirical research is needed to examine the impact of the application of Augmented Reality on various aspects of learning, such as concept understanding, learning motivation, and students' critical thinking skills (Danaei et al., 2020) By adopting a holistic approach, in which technical, pedagogical, and social aspects are addressed simultaneously, the application of Augmented Reality in primary schools can not only become more effective, but also have a significant positive impact on the overall quality of education (Howorth et al., 2024).

The application of Augmented Reality in primary schools presents a great opportunity to revolutionize the traditional way of learning, making it more engaging, relevant, and in tune with the development of modern technology (Zuhri et al., 2024) Augmented Reality technology enables the delivery of interactive and visual learning materials (S. Li et al., 2024) thereby stimulating students' interest and increasing their engagement in the learning process (Grinshkun et al., 2021) By utilizing elements of 3D visualization, dynamic simulation, and

immersive experiences, Augmented Reality can help students understand complex concepts more easily than conventional methods (Chen et al., 2024) However, for this opportunity to be utilized optimally, close collaboration between various interested parties is needed (Panwar et al., 2024) Policymakers need to create regulations and policies that support technological innovation in Education (Capecchi et al., 2024) including budget allocation for the procurement of Augmented Reality devices and teacher training (Khilya, 2023)

On the other hand, technology providers have an important role to play in developing Augmented Reality devices and applications that are user-friendly, affordable, and tailored to educational needs at the primary school level (Yende, 2024) Educators are also key to the successful implementation of Augmented Reality, by ensuring these technologies are effectively integrated into the curriculum (Beisenbayeva et al., 2024) supported by relevant learning strategies (Psalidou et al., 2023) In addition, the ever-evolving Augmented Reality technology allows schools to reach more students and provide a personalized learning experience (Jhuang et al., 2024) With a planned approach, where technology is not only a supporting tool but also an integral part of the learning ecosystem (Velarde-Camaqui & Sanabria-Z, 2024) Augmented Reality can be a catalyst for educational transformation, creating a generation of students who are not only proficient in technology but also have a deep and relevant understanding of learning materials (Salleh et al., 2023). If implemented holistically, this approach has the potential to transform the educational paradigm in elementary schools, making them more responsive to the demands of the digital era.

CONCLUSION

Based on the analysis of 35 articles, the majority of studies were conducted in 2023 and 2024. Based on the countries in which this study was conducted, 25 countries are represented, with Indonesia, Greece, and Portugal being the most represented. Meanwhile, the methods used are quantitative (21), mixed methods (6), research and development (5), and qualitative (3). Obstacles to implementing augmented reality-based learning media identified in the literature review include limitations in infrastructure, teacher competence, and technology compatibility, which can hinder implementation. However, the study also finds great opportunities in using Augmented Reality, including project-based learning and collaborative approaches, 21st century upskilling, and increasingly user-friendly technological developments. Prospects include the development of affordable and inclusive Augmented Reality-based learning models, supported by collaboration between policymakers, technology providers, and educators. Further research is needed to examine in greater depth the impact of Augmented Reality on learning outcomes across various educational contexts, including the role of teacher training in optimizing its use. In addition, broader data-driven evaluations must be conducted to bridge the technology access gap between developed and remote regions.

The findings of this systematic literature review suggest that successful integration of Augmented Reality in elementary education requires a comprehensive approach that addresses technological readiness, pedagogical alignment, infrastructure availability, and teacher competence. Future research should conduct longitudinal, comparative studies across

diverse educational contexts to examine the long-term impact of Augmented Reality on learning outcomes and to develop standardized evaluation frameworks for the implementation of Augmented Reality-based learning. In practice, educators and schools should prioritize curriculum-aligned, project-based Augmented Reality learning designs, supported by continuous professional development, to strengthen teachers' technological pedagogical content knowledge. At the policy level, governments and educational institutions are encouraged to invest in digital infrastructure, promote equitable access through affordable Augmented Reality solutions, and establish clear regulatory guidelines and monitoring mechanisms to ensure the sustainable and inclusive implementation of Augmented Reality in elementary schools.

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