Prerequisites for Teachers to Implement Augmented Reality: A Systematic Review

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Abstract: *The use of Augmented Reality (AR) in teaching and learning, and the pivotal role teachers play in this process has been widely recognized. However, the prerequisites for effective implementation by teachers and their specific needs remain unclear. This systematic literature review aimed to elucidate the role of teachers in AR education studies and identify the prerequisites for their competency in integrating AR into teaching and learning. The findings revealed a lack of focus on specific teaching strategies and limited attention to AR-related professional development (PD) for teachers. Practice-based collaborative teacher training was proposed as an effective approach for enhancing teachers' competency in AR implementation.*

Keywords: Augmented Reality, Teacher's role, Systematic review, K12

1. Introduction

Over the past decade, there has been an increase in the number of Augmented Reality (AR) applications used in the field of education (Chang et al., 2023). The value and effectiveness in using AR for facilitating teaching and learning has been well established (López-Belmonte et al., 2020). Its immersive qualities, achieved through the overlay of digital information on the real world, facilitate real-time interactions with both real and virtual elements (Azuma et al., 2001), thereby enriching learning experiences through its multimodal qualities, interactivity, and capacity to elucidate abstract concepts (Wen et al., 2023). Despite the advantages of AR in education, it is essential to acknowledge the challenges educators may face in integrating it into their teaching practices. It requires teachers to be sufficiently trained in using AR technologies (López-Belmonte et al., 2020; Nikou et al, 2023). While educators envision the advantages in adopting AR-enhanced instructional methods, they may be lacking in the necessary competencies for AR implementation (Nikou et al, 2023). However, there is a scarcity of studies examining prerequisites for teachers to integrate AR in teaching and learning (Nikou et al., 2023).

Studies have identified prerequisites for implementing ICT in educational practices (e.g., Heitink et al., 2016; Kippers et al., 2018; Spiteri & Rundgren, 2020). Spiteri and Rundgren (2020) conducted a systematic review exploring factors affecting primary teachers' use of digital technology and identified four main areas, including the school culture, teachers' knowledge, attitude, and skills. Similar findings were highlighted by Heitink et al. (2016) and Kippers et al. (2018). These studies emphasized the importance of teachers' self-awareness,

understanding of students, and familiarity with technology. Additionally, Spiteri and Rundgren (2020) emphasized the impact of school culture on teachers' knowledge, attitudes, and skills. A supportive school culture enhances teachers' PD by promoting collaboration, reflection, and knowledge sharing (Tondeur et al. 2017). School culture, highlighted by Heitink et al. (2016) and Kippers et al. (2018), includes factors such as support from school leaders and teacher collaboration.

Therefore, this systematic review on the prerequisites for teachers to implement AR activities was conducted by considering both dimensions of teachers and school context. It combined findings from papers published between 2011 to 2023 to provide an overview of teachers' role in AR-related implementations in K12 schools. The study aimed to deepen understanding of the prerequisites for effectively implementing AR in the classroom and, more specifically, to provide suggestions for teachers' PD to enhance their ability to integrate AR into teaching and learning. To achieve this, the study will address the following two questions: (1) What are the purposes of existing AR-related studies investigating the role of teachers? and (2) What teacher-related prerequisites need to be considered to ensure the effectiveness of AR-supported teaching and learning?

2. Methodology

2.1. Searching Procedure

To address our research questions, we followed the PRISMA framework, comprising four phases: identification, screening, eligibility, and inclusion. Three databases (ERIC, WOS, and ES) were searched for literature on AR in education. We limited the search terms to "Augmented Reality" AND ("Teachers" OR "Educators" OR "School Staff") AND ("Classrooms" OR "Classroom Environment") across all databases. The search spanned from 2005 to 2023, yielding 314 results in the identification stage. After removing 24 duplicates, 290 articles proceeded to the screening stage. Eligibility was checked in three rounds. Round 1 involved reviewing titles, abstracts, and accessing full texts as needed, eliminating studies lacking empirical findings, not in English, not K-12 focused, or not specific to AR. We developed inclusion criteria, including scientific, peer-reviewed publications, empirical research, K-12 context, AR in classroom practice, and English full texts, resulting in 102 articles after round 1. Round 2 added criteria to exclude studies on pre-service teachers or lacking research questions about teachers, resulting in 67 exclusions. The focus shifted to understanding teachers' roles and experiences, excluding pre-service teachers. Additionally, studies without specific research questions about teachers were excluded. The remaining 35 articles underwent full-text screening, resulting in the exclusion of 15 conference proceedings and one article with insufficient information. Two more articles were identified through snowballing. The screening process concluded with 22 review articles.

2.2. Data Coding and Data Analysis

Our analysis consists of three stages. Firstly, we synthesized the findings from the 22 selected papers, identifying their research purposes, delineating the role of teachers, and extracting prerequisites for successful implementation reported in these studies. Secondly, we analyzed teacher-related prerequisites through the lens of

ICT implementation in classrooms, drawing from Heitink et al.'s (2016) and Kippers et al.'s (2018) studies as theoretical foundations. This guided the development of coding categories, which were further refined based on findings from the reviewed papers. The second and third authors independently coded the data. Thirdly, the first author clustered similar prerequisites into sub-categories, incorporating input from the other two authors, and the final dimensions of categories were confirmed collaboratively. This process was inductive, driven by the prerequisites identified in the selected studies.

3. Results

3.1. Purposes of Existing AR-related Studies Investigating the Role of Teachers

The selected papers investigating the role of teachers can be categorized into four groups based on their research objectives. The first category discusses teachers' general perspectives on integrating AR into classrooms (N=6, 27.3%). The second category focuses on teachers' feedback on specific AR-based learning designs, with most studies falling into this category (N=12, 54.5%). The third category explores teacher scaffolding strategies in AR-based learning and their effects (N=1, 4.5%). The fourth category centers on AR-related teacher training and its effects (N=3, 13.6%).

As shown in Table 1, when investigating teachers' perspectives on AR, most studies use semi-structured interviews and surveys for open coding and descriptive statistics to obtain feedback from teachers on attitudes and skills in using AR. These studies focusing on specific AR design primarily adopt a case study approach, conducting thematic and content analysis through surveys, interviews, and observations to investigate feedback from students and teachers. Additionally, in a few studies, classroom artifacts (lesson plans, final papers, etc.) or log data were used to supplement the findings of specific AR design effects. While acknowledging the importance of teachers in AR-based learning, few studies delve into specific scaffolding strategies for enhancing its effects. Moreover, limited attention is given to teachers' PD, with some studies suggesting the effectiveness of certain training approaches, such as TSED learning design by Buchner and Hofmann (2022), and others demonstrating the implementation process of teacher PD programs through design-based research (Ilona-Elefteryja et al., 2020; Meletiou-Mavrotheris et al., 2020).

Table 1. Purposes and approaches of AR-related studies investigating the role of teachers

Categories	Numbers	Research methods	Data sources
1. Teachers' view of using AR	6	Survey study (N=4) Case study (N=2)	• Questionnaires • Interview • Documents

2. Effectiveness of specific AR design	12	Survey study (N=2) Case study (N=7) Experimental/quasi- design (N=2) Design-based research (N=1)	• Questionnaires • Interview • Observation and field notes • Reflection journal • Class artifacts (lesson plan, documents, final papers) • Log data
3. Specific teaching strategies or mechanisms	1	Experimental design (N=1)	• Test • Interview
4. AR-related teacher training and its effects	3	Quasi-experimental design (N=1) Design-based research (N=1) Others (N=1)	• Questionnaire • Interviews • Activity reports

3.2. Teacher-related Prerequisites for Implementing AR

Table 2 outlines the literature on AR in education, specifying teacher-related prerequisites for AR implementation in classrooms across four categories: teachers' knowledge and skills, attitudes and beliefs, leadership and culture, and support and professional development. Key knowledge and skills required for teachers to effectively integrate AR into teaching and learning encompass: (1) proficiency in AR technology and its applications, (2) adeptness in integrating AR content and pedagogy into subject-specific teaching, and (3) ability to provide guidance to students during AR activities. Concerning attitudes and beliefs, teachers should demonstrate: (1) a willingness to learn and utilize AR technology, integrating it into curricula, (2) belief in AR's educational benefits, and (3) confidence in implementing AR activities.

Moreover, contextual factors within the school environment play a crucial role in successful implementation. Prerequisites related to leadership and culture entail: (1) alignment of leadership vision with teachers' objectives, and (2) a culture fostering collaboration and professional learning communities. Support and effective professional

development programs are essential for successful AR integration. These include: (1) technical and financial assistance, (2) flexible and adaptive curricula, and (3) practice-centered collaboration within professional development programs.

Table 2. Teacher-related prerequisites for the implementation of AR

Teacher	
Knowledge and skills	**Knowledge and skills of AR familiarity and technical proficiency** • Familiarity and experience with AR technology, including AR devices, applications, and platforms (Pan et al., 2021; Ilona-Elefteryja et al., 2020) • Utilizing AR's affordances while planning the lesson outline (Tillman et al., 2019) • Ability to deal with basic technical issues related to AR (Ilona-Elefteryja et al., 2020) **Knowledge and skills of integrating AR content and pedagogy into teaching subjects** • The ability to create AR contexts for lesson plans (Tillman et al., 2019) • Proficiency in flexibly integrating AR into curricula, including selecting the specific AR application and using AR materials (Ashely-Welbeck & Vlachopoulos, 2020), and modifying them to meet teaching needs (Squire, 2010) • Incorporating educational content from other disciplines using AR (Ilona-Elefteryja et al., 2020) • Selecting, using, and even creating appropriate AR applications suitable for specific teaching subjects (Nikou et al., 2023) **Knowledge and skills of providing guidance to students during AR activities** • Playing a guiding role rather than merely providing information (Squire, 2010)
Attitude and beliefs	**Willingness to learn and use AR technology, and to incorporate it into curricula** • Positive attitude toward AR technologies (Marín-Díaz et al., 2022)

- Willingness to invest time in creating AR content and lessons (Ilona-Elefteryja et al., 2020).

- Willingness to incorporate AR into curriculum (Buchner & Hofmann, 2022),

- Willingness to modify task structures when implementing AR (Mitchell, 2011).

Beliefs in the educational benefits that AR can offer

- Believing that AR technology will be genuinely useful for teaching (Tillman et al., 2019) and will

  lead to positive learning outcomes (Marín-Díaz et al., 2022).

Confidence of implementing AR activities

- Confidence in engaging students in AR class activities (Meletiou-Mavrotheris et al., 2020).

Context	
Leadership and culture	**Alignment of leaders' version with teacher's objective**

- The alignment of leaders' vision for integrating AR into the educational environment with the

  objectives set by teachers. (Huang et al., 2016).

- Deciding on the areas and levels of using AR in education (Nikou et al., 2023)

Culture of collaboration and professional learning communities

- Establishing a culture that fosters collaborative efforts among teachers, administrators, and

  instructional designers (Perifanou et al., 2022)

- Creating a community that encourages the exchange of ideas, materials, expertise, feedback, and

  best practices related to AR (Meletiou-Mavrotheris et al., 2020; Perifanou et al., 2022)

Support and Professional development	**Technical and financial support**

- Leadership's active support for AR integration, involving the provision of resources, equipment

  (Squire, 2010), training programs, and expertise to facilitate AR adoption (Ilona-Elefteryja et al.,

  2020).

- Allocating the necessary time for preparing and implementing AR activities, (Huang et al., 2016),

  along with providing technical and financial support (Huang et al., 2016)

Flexible and adaptive curricula

- Adaptive curricula enabling teachers to customize materials to local needs. (Squire, 2010).

Practice-centered collaboration

- Empowering teachers to gain confidence and competence in AR usage. (Nikou et al., 2023)

- Encouraging exchange of lesson plans, expertise and codesign educational activities based on

  specific AR-enabled teaching approach (Meletiou-Mavrotheris et al., 2020)

6. Discussion and Conclusion

The results suggest that few studies pay attention to the specific teaching strategies or mechanisms that can be used to ensure the effects of AR-based learning. This finding is consistent with the claim by Garzón et al. (2020) in their review study that minimal guidance during instruction was not sufficient in existing AR studies. Meanwhile, the results of the present review demonstrate that only a small number of studies concentrated on AR-related PD for teachers. Based on the existing research, the prerequisites for teachers' abilities and attitudes towards integrating AR into classroom teaching are like those of using other ICT tools. Teachers need to be familiar with the tools, integrate the tools with teaching methods and curriculum content, and know how to manage classroom activities. In terms of attitude, teachers are willing to actively understand and learn to use the tools, believe in their teaching value, and can confidently use the tools.

However, the uniqueness of using AR lies in its emphasis on the integration of tools with curriculum content. This is because the use of AR involves the visualization of specific knowledge points, enabling learners to have a better understanding of abstract concepts, thus requiring consideration of specific course needs for students of different grade levels. The flexibility of the curriculum has been proposed as an important factor for the effective implementation of AR activities. Additionally, the importance of technology and financial support is underscored, given the relatively high development costs associated with AR activities. The willingness of school leaders, alignment of teachers' goals, and a collaborative culture align with prerequisites observed in other effective curriculum reforms.

Practice-based collaborative teacher training is highlighted as an effective approach to teachers' PD for designing and implementing AR activities. Studies have indicated that PD should provide regular opportunities for teachers to be involved in active learning and reflection on it with their colleagues (Garet et al., 2001). Furthermore, effective PD should be situated within an authentic and contextualised learning community and

allows educators to learn practical solutions from their peers (Webster-Wright, 2009). However, the findings of this review suggest that existing AR studies related to teacher's roles only focused on small-scale PD initiatives, despite the emphasis on collaboration among teachers. Our results encourage future studies on large-scale and longitudinal AR-related PD at the community level.

This review study has certain limitations as well. First, some relevant studies might not have been included due to the search terms and databases considered in this review. Second, the studies published before 2011 and after August 2023 were not included. Third, as articles specifically focusing on teacher education in AR environments are limited, in some selected studies, teachers' role was merely investigated in one of the research questions rather than the central focus of the entire study.

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References

Ashely-Welbeck, A., & Vlachopoulos, D. (2020). Teachers' perceptions on using Augmented Reality for language learning in Primary Years Programme (PYP) education. *International Journal of Emerging Technologies in Learning*, *15*(12), 116-135. https://doi.org/10.3991/ijet.v15i12.13499

Buchner, J., & Hofmann, M. (2022). The more the better? Comparing two SQD-based learning designs in a teacher training on augmented and virtual reality. *International Journal of Educational Technology in Higher Education*, *19*(1). https://doi.org/10.1186/s41239-022-00329-7

Heitink, M. C., Van der Kleij, F. M., Veldkamp, B. P., Schildkamp, K., & Kippers, W. B. (2016). A systematic review of prerequisites for implementing assessment for learning in classroom practice. *Educational Research Review, 17*, 50–62. https://doi.org/10.1016/j.edurev.2015.12.002

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915–945.

Garzón, J., & Acevedo, J. (2019). Meta-analysis of the impact of Augmented Reality on students' learning gains [Review]. *Educational Research Review*, *27*, 244-260. https://doi.org/10.1016/j.edurev.2019.04.001

Huang, Y., Li, H., & Fong, R. (2016). Using Augmented Reality in early art education: a case study in Hong Kong kindergarten. *Early Child Development and Care*, *186*(6), 879-894.

Ilona-Elefteryja, L., Meletiou-Mavrotheris, M., & Katzis, K. (2020). Augmented reality in lower secondary education: A teacher professional development program in Cyprus and Greece. *Education Sciences*, *10*(4).

Kippers, W. B., Wolterinck, C. H. D., Schildkamp, K., Poortman, C. L., & Visscher, A. J. (2018). Teachers' views on the use of assessment for learning and data-based decision making in classroom practice. *Teaching and Teacher Education*, *75*, 199-213. https://doi.org/10.1016/j.tate.2018.06.015

Marín-Díaz, V., Sampedro, B., & Figueroa, J. (2022). Augmented Reality in the Secondary Education classroom: Teachers' Visions. *Contemporary Educational Technology*, *14*(2).

Meletiou-Mavrotheris, M., Carrilho, A. R., Charalambous, C., Mavrou, K., & Christou, C. (2020). Teacher training for 'augmented reading': The living book approach and initial results. *Education Sciences*, *10*(5).

Mitchell, R. (2011). *Alien Contact!: Exploring Teacher Implementation of an Augmented Reality Curricular Unit* (Jl. of Computers in Mathematics and Science Teaching, Issue.

Nikou, S. A., Perifanou, M., & Economides, A. A. (2023). Development and validation of the teachers' augmented reality competences (TARC) scale. *Journal of Computers in Education*.

Pan, Z., López, M. F., Li, C., & Liu, M. (2021). Introducing augmented reality in early childhood literacy learning. *Research in Learning Technology*, *29*(1063519), 1-21. https://doi.org/10.25304/rlt.v29.2539

Perifanou, M., Economides, A. A., & Nikou, S. A. (2022). Teachers' Views on Integrating Augmented Reality in Education: Needs, Opportunities, Challenges and Recommendations. *Future Internet*, *15*(1), 20-20.

Spiteri, M., Chang Rundgren, SN (2020). Literature Review on the Factors Affecting Primary Teachers' Use of Digital Technology. *Technology, Knowledge and Learning 25*, 115–128. https://doi.org/10.1007/s10758-018-9376-x

Squire, K. (2010). From information to experience: Place-based augmented reality games as a model for learning in a globally networked society. *Teachers College Record*, *112*(10), 2565-2602.

Tillman, D., Alvidrez-Aguirre, V., Kim, S. J., & An, S. (2019). *Teachers' Conceptions of the Pedagogical Potential for Classroom-based Augmented Reality* (Journal of Educational Multimedia and Hypermedia, Issue.

Tondeur, J., van Braak, J., Siddiq, F., & Scherer, R. (2016). Time for a new approach to prepare future teachers for educational technology use: Its meaning and measurement. *Computers & Education*, *94*, 134-150.

Webster-Wright, A. (2009). Reframing Professional Development Through Understanding Authentic Professional Learning. Review of Educational Research, 79(2), 702-739.

Wen, Y. Wu. L., He. S. J., Ng., H-E., Teo., B. C., Looi, C-K. & Cai, Y. (2023) Integrating Augmented Reality into Inquiry-based Learning Approach in Primary Science Classrooms, *Educational Technology Research & Development*. *71*, 1631–1651.