

Interactive AR Prototype Pipeline Augmented Reality Textbook Literacy Learning Materials in Indigenous Education: A Mini Review

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Abstract: *This mini review examines the current state and educational relevance of the Interactive Augmented Reality (AR) Prototype Pipeline in developing literacy learning materials for Indigenous education. As digital learning technologies evolve, AR offers a promising approach to bridging literacy gaps through interactive, culturally responsive content. The review focuses on how this prototype pipeline supports literacy enhancement, virtual learning, and cultural knowledge sharing. A systematic literature search was conducted across databases including Scopus, ScienceDirect, Springer, and Google Scholar using key terms such as “augmented reality,” “prototype,” “indigenous,” “education,” and “interactive.” Studies included in the review specifically addressed the integration of AR into textbook development for Indigenous learners and provided insights into the strengths, limitations, and potential applications of such tools. Key findings highlight that AR-integrated textbooks improve learner engagement, facilitate multisensory learning, and promote cultural relevance through embedded traditional stories and visuals. Core technologies identified include mobile AR, 3D visualization, and image recognition. Despite these benefits, several limitations were noted, including technological access barriers in rural areas, limited co-creation with Indigenous communities, and a lack of longitudinal studies to measure long-term learning outcomes. There are also ongoing debates about cultural authenticity and the scalability of AR tools in diverse educational settings. The review concludes that while the Interactive AR Prototype Pipeline holds significant promise for transforming literacy education in Indigenous contexts, further research is needed. Future directions should emphasize community-driven design, teacher training, and the development of robust evaluative frameworks. Addressing these challenges is crucial to ensure that AR literacy materials are both effective and inclusive, supporting sustainable educational innovation for Indigenous learners.*

Keywords: Augmented Reality; Interactive AR Textbooks; Literacy Learning; Indigenous Education; Design-Based Research

1. Introduction

In an era where digital technologies are reshaping the educational landscape, augmented reality (AR) has emerged as a transformative tool to enhance learning experiences (Noraini & Ekram, 2024; N. B. Ramli et al., 2023; Santano et al., 2024a). This capability is especially important in the context of (PORRAS et al., 2025), where conventional literacy materials often fail to reflect cultural relevance or address diverse learning needs (Salas-Pilco et al., 2023). The interactive AR prototype pipeline is a structured approach to the development of AR-integrated textbooks (Li et al., 2023). This prototype offers new potential to bridge literacy gaps through immersive, engaging, and culturally responsive content (Barrientos-Avenidaño et al., 2019).

Present research is still fragmented (N. Ramli et al., 2023; Sari et al., 2024a), and there is limited consensus on its long-term effectiveness, scalability, and cultural appropriateness (Kasar et al., 2025; Kleftodimos et al., 2023). This conclusion is despite the fact that there is a growing interest in Augmented Reality (AR) for Indigenous literacy education. Some research stresses its motivational appeal and visual interactivity, while others challenge its accessibility and alignment with Indigenous knowledge systems (Hung et al., 2025; N. Ramli et al., 2024).



Figure 1: The 3M Celik application pipeline process's AR application simulation

Figure 1 depicts the Celik 3M Interactive AR Textbook Pipeline, highlighting a six-step process for scanning, touching, interacting, speaking, displaying, and developing. This process is intended to facilitate immersive literacy learning for Indigenous students. This pipeline of AR applications is in direct alignment with the expanding discussion regarding the application of augmented reality in education, particularly in Indigenous communities where conventional materials frequently lack cultural relevance. Although the paragraph emphasizes fragmented research and concerns regarding scalability, effectiveness, and cultural appropriateness, the figure illustrates a structured, learner-centred approach that addresses these issues through multisensory engagement, contextual content, and interactive experiences. The technological potential for scalability and sustainability is further emphasized by the integration of tools such as Unity and Vuforia, which render the Celik 3M pipeline a practicable solution to the current gaps in AR-based Indigenous literacy education.

This mini review aims to clarify ongoing debates by synthesizing recent findings on the implementation of the Interactive AR Prototype Pipeline in the development of AR-integrated textbook materials for Indigenous education (Kholiq, 2020; Putra et al., 2024; Susanto & Nurtamam, 2024). This addresses the important information gaps related to implementation techniques, educational results, and contextual problems. The review is organized around four primary topics: the improvement of literacy, fundamental technologies, the advantages and disadvantages, and the potential for future paths. Overall, the findings indicate that augmented reality has the potential to improve literacy by utilizing multimodal engagement and material that is culturally specific (AlGerafi et al., 2023; Susanto & Nurtamam, 2024). However, there are still obstacles to overcome, such as constraints in infrastructure, the preparation of teachers, and the requirement for materials that are culturally co-created (Moreno-Fernández et al., 2023). The purpose of this study is to highlight the significance of conducting research that is more inclusive, longitudinal, and community-driven in order to support future educational practices and innovation.

2. Methods

A comprehensive literature search was conducted using [list databases, e.g., PubMed, Scopus, ScienceDirect, Springer, Google Scholar]. Keywords such as ("augmented reality" OR "AR" OR "mixed reality" OR "virtual reality") AND ("prototype" OR "model" OR "simulation" OR "demonstration") AND ("indigenous" OR "native" OR "aboriginal" OR "first nations") AND ("education" OR "learning" OR "teaching" OR "curriculum") AND ("interactive" OR "engagement" OR "participatory" OR "hands-on") “augmented reality, prototype, indigenous, education and interactive” were utilized to collect relevant articles. Various types of articles, including original research, systematic reviews, meta-analyses, case studies, journal editorials, and commentaries, were considered for this mini-review.

Below, we provide the inclusion and exclusion criteria for studies in this review article.

2.1 Inclusion Criteria

This mini review included studies that:

- Discuss the Interactive AR Prototype Pipeline in the context of AR textbook literacy materials.
- Focus on the application of AR technology in Indigenous literacy education.
- Analyse the strengths, limitations, or potential applications of AR textbooks in educational settings.
- Are published in English.

2.2 Exclusion Criteria

- Studies not published in English.
- Studies that discuss Indigenous literacy education without explicit reference to the Interactive AR Prototype Pipeline or AR textbook materials.
- Grey literature, including:
 - i. Conference abstracts
 - ii. Unpublished reports
 - iii. Non-peer-reviewed sources

3. Discussion and Results

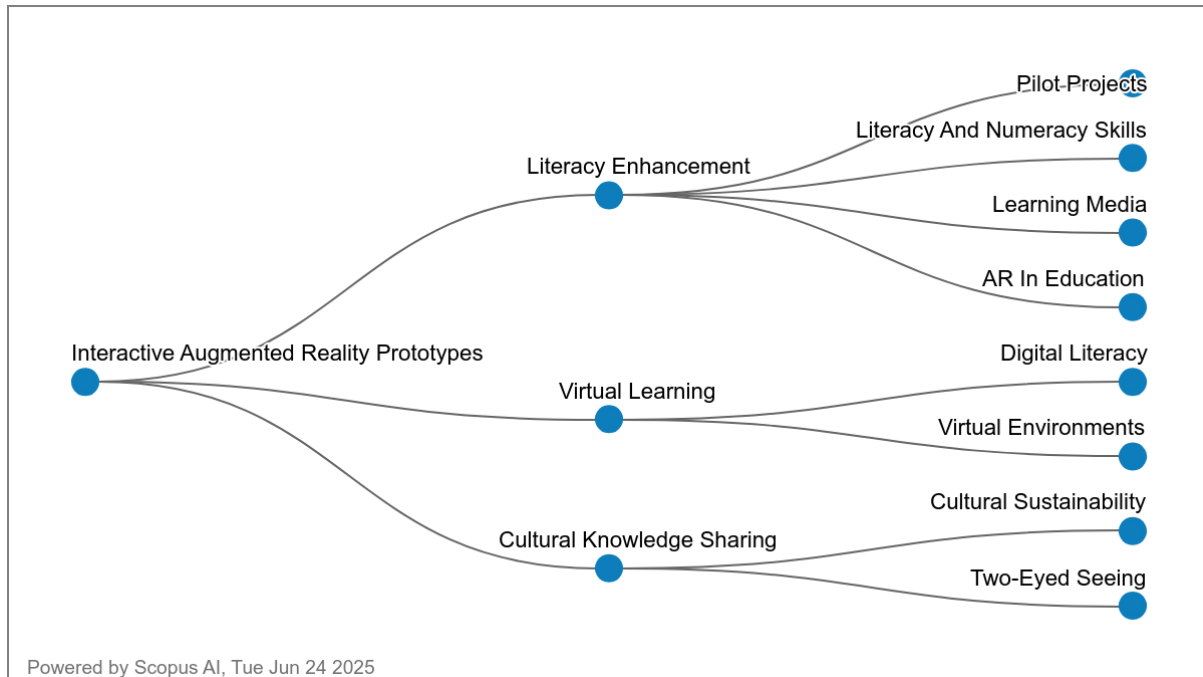


Figure 2: Concept Map of Interactive Augmented Reality prototype

3.1 Current Status of Interactive AR Prototype Pipeline for Augmented Reality Textbook Literacy Learning Materials in Indigenous Education Based on Theme Literacy Enhancement

The Interactive AR Prototype Pipeline improves Indigenous literacy by incorporating AR into culturally pertinent textbooks (Sari et al., 2024b). Presently, there is evidence of enhanced comprehension and engagement. Mobile AR and 3D modeling are among the most significant technologies (Hutson, 2024; Izard et al., 2020; Kabulunze et al., 2023). Challenges include content co-creation and access, while benefits include contextual learning and motivation. In order to optimize (Ade-Ibijola et al., 2025) Future research should investigate scalability, cultural integration, and long-term impact.

3.2 Current Status of Interactive AR Prototype Pipeline for Augmented Reality Textbook Literacy Learning Materials in Indigenous Education Based on The Theme of Virtual Learning

Through the integration of AR with culturally pertinent textbooks, the Interactive AR Prototype Pipeline facilitates virtual literacy learning in Indigenous education (Chen et al., 2021; David H. Smith et al., 2021; Hung et al., 2025; Respati et al., 2024). It promotes inclusivity and engagement in remote environments. 3D visualization and mobile AR are among the most significant technologies (Imbert et al., 2013; Molka-Danielsen et al., 2010). Opportunities for immersive learning exist; obstacles include digital equity and accessibility (Kaur, 2023; Knotte et al., 2016; Silva et al., 2022). Community-led, scalable models that respect Indigenous knowledge systems and improve virtual learning should be the focus of future research (Ade-Ibijola et al., 2025; Li et al., 2023).

3.3 Current Status of Interactive AR Prototype Pipeline for Augmented Reality Textbook Literacy Learning Materials in Indigenous Education Based on Theme Cultural Knowledge Sharing

Through the integration of traditional stories and symbols into AR literacy textbooks, the Interactive AR Prototype Pipeline fosters the exchange of cultural knowledge in Indigenous education (Irham et al., 2024; Santano et al., 2024b; Yang, 2023). The preservation of heritage is achieved through the promotion of literacy (Botilias et al., 2021; Huang et al., 2024; Hutson, 2024). Two of the most significant technologies are 3D storytelling and image recognition (Hite et al., 2025; “Proceedings - IEEE 20th International Conference on Advanced Learning Technologies, ICALT 2020,” 2020). Benefits include cultural relevance; challenges include authenticity and co-creation (Kleftodimos et al., 2023; Sogemeier et al., 2023). In the future, research should prioritize Indigenous-led design and investigate how AR facilitates the transmission of knowledge across generations in the field of education (Boray et al., 2025; Hutson, 2024).

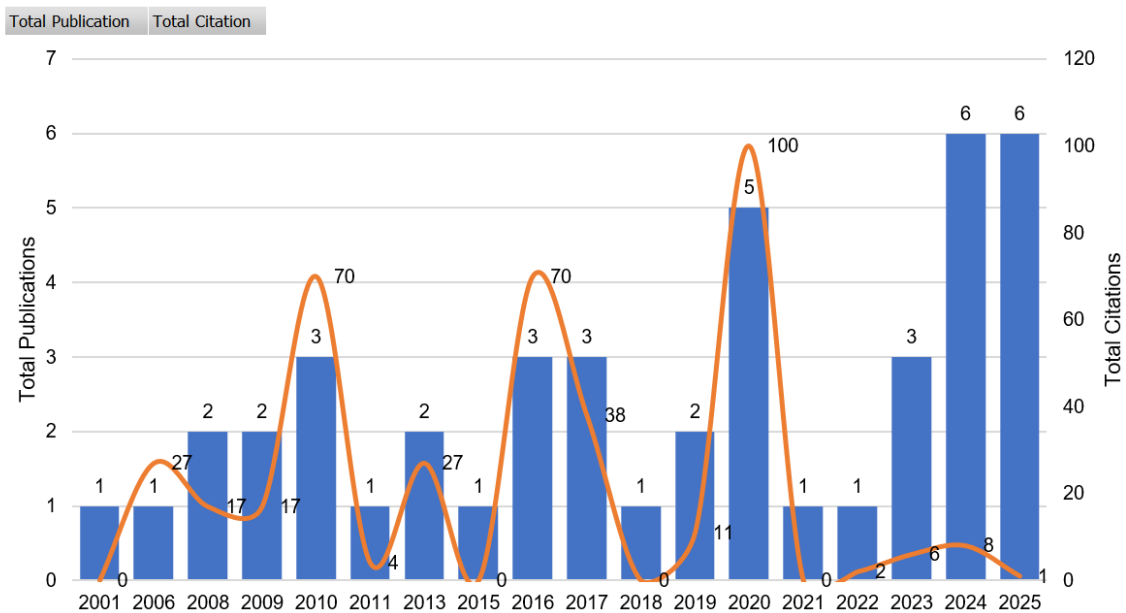


Figure 2: Total publications and total citations by year

The graph depicts publication trends that are prone to fluctuations, with noteworthy citation peaks occurring in the years 2010, 2016, and 2020. In the years 2024 and 2025, there was an increase in the number of publications; however, the citation rates remained low. This suggests that there has been a recent uptick in interest in the topic; however, the long-term academic effect of the field has not yet been thoroughly established.

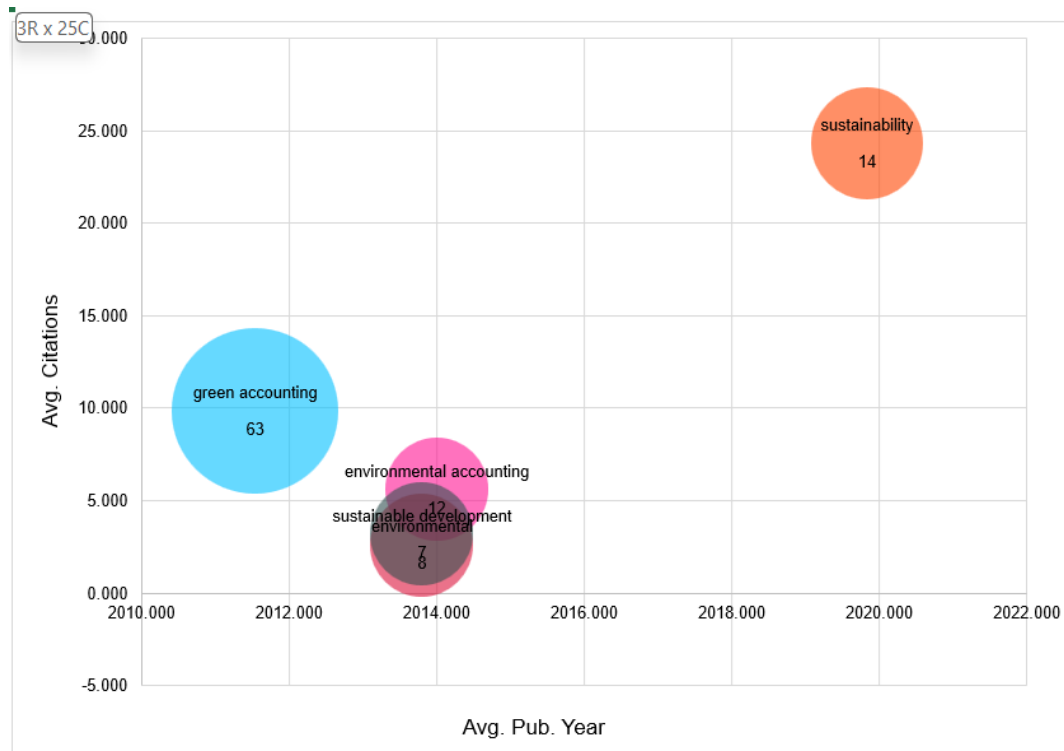


Figure 3: Temporal and Citation Impact of Top 10 Most Cited based on Average Citations of Index Keywords (Min. Freq. =5, Bubble Size = Documents)

The figure highlights “sustainability” as a recent and highly cited topic, whereas “green accounting” holds the highest average citations despite being associated with earlier publication years. “Environmental accounting” and “sustainable development” show moderate impact, indicating a growing yet diverse level of interest across environmental and accounting-related themes.

4. Conclusion

This mini review highlights the promising role of the Interactive AR Prototype Pipeline in advancing literacy learning and cultural relevance within Indigenous education. Key findings reveal that AR-integrated textbooks enhance engagement, support multisensory learning, and promote cultural knowledge sharing. However, limitations persist, including technological access, lack of Indigenous-led content development, and insufficient long-term impact studies. Unresolved issues such as content authenticity and scalability also remain. Future research should focus on community-driven design, infrastructure support, and evaluative frameworks to ensure sustainable implementation. Addressing these gaps is essential to fully realize the potential of AR as an inclusive and transformative educational tool.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this study.

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