Cultivating Authenticity: A Framework for Instructional Design in Augmented Reality (AR) Storytelling

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Augmented reality (AR) facilitates student engagement by seamlessly intertwining digital content with real-world objects. AR elicits emotional responses through a sense of presence, offering an immersive and enjoyable learning experience through hands-on activities. Similarly, storytelling enhances self-esteem, develops critical thinking, and teaches cultural sensitivity and communication skills. However, few researchers have explored the potential of AR technology for digital storytelling. This paper introduces an instructional design framework that utilizes AR

technology as a digital storytelling tool to support authentic learning, enriching the overall learning experience and cultivating the potential at the intersection of AR and authentic learning.

Introduction

Augmented reality (AR) is a digitally generated, synchronized layer that pairs with the physical environment to provide additional information to augment and enrich the real-world context (Carmigniani & Furht, 2011). It offers immersive learning activities that simulate real-life experiences and has been claimed to enhance cognition and foster culturally responsive and meaningful social interactions to facilitate deep learning (MacDowell & Lock, 2023). One way in which AR is thought to assist learning is by facilitating authentic inquiry through a multisensory experience and incorporating multimedia elements that motivate students to engage in learning activities (Cheng & Tsai, 2013; Dede, 2005).

This research introduces an instructional design framework centred around AR immersive storytelling to explore how AR, as a digital medium, can create an authentic learning environment and deliver authentic learning tasks through its ability to enhance student engagement. This study aims to explore intersections among authenticity, AR, and storytelling that can contribute to learning. First, I place the instructional design framework into context with a comprehensive review of current literature on digital storytelling, AR technology in education, and authentic learning theory. I then present the design framework, which is based on an AR case study and draws from Herrington and Oliver's (2000) key elements of authentic learning, to illustrate how AR can foster an authentic learning environment tailored for digital storytelling activities.

Literature Review

AR Technology in Education

AR encompasses the real-time integration of digital text, imagery, animations, or videos within users' natural sensory experiences, enriching their perception of the physical environment by overlaying digital information onto the real world and ensuring these virtual enhancements interact dynamically with physical spaces, thereby offering a seamless blend of virtual and real elements (Akçayır & Akçayır, 2017; Azuma, 1997). Lin and Yu (2023) conducted a meta-analysis of the effects of AR technologies in interactive learning environments. Their study reported that implementing AR significantly enhanced attitudes toward learning (0.98 SD), engagement in the learning activity (0.74 SD), interest (0.93 SD), and flow experience (0.44 SD). These enhancements are attributed to AR's ability to offer

interactive, novelty, and immersive learning experiences, as well as reduce cognitive load in learning. One aspect of learning enhancement is AR's unique immersive interface, which "draw[s] on the power of situated learning by enabling digital simulations of authentic problem-solving communities in which learners interact with other virtual entities (both participants and computer-based agents) who have varied levels of skills" (Dede, 2009, p. 66). The AR interface not only creates authenticity but also fosters a social experience in learning, as indicated by Miller et al. (2019). Their study revealed that AR influences social dynamics, showing how the presence of virtual elements within real-world settings alters task performance, nonverbal communication, and social connectedness. Therefore, the influence of AR in education appears to be multifaceted and holds promise beyond its initial technological appeal.

Digital Storytelling

Instructional Benefits. From an instructional design point of view, storytelling is one of the authentic learning activities recognized as an effective instructional tool: providing a meaningful context to attract students' interest, making learning a pleasant process, fostering deeper understanding, and promoting active, situated, meaningful, and reflexive learning processes (Lemonidis & Kaiafa, 2019; Marsico et al., 2019). With the growth of digital hand-held devices, apps, and editing software tools, educators have started to use various digital stories as effective instructional tools, improving instruction and helping students comprehend learning in difficult contexts (Alismail, 2015). Students are also creating their own stories via digital tools and social media platforms (Kara et al., 2020). These informal and voluntary educational activities enable student-centered pedagogy and grant students the agency to manage their own learning and reflect on their own educational experiences (Makarova & Pirozhkova, 2020; Peng & Hwang, 2021).

Research offers significant insights into the impact of digital storytelling on learning outcomes. Sadik (2008) used a digital story evaluation rubric, observations, and interviews to conduct quantitative and qualitative analyses of the effectiveness of digital storytelling. His results showed that digital storytelling can enhance students' interest in learning topics, deepen their understanding, and enable them to translate complex subjects effectively, which promotes authentic learning tasks and fosters engagement. More recently, Wu and Chen (2020) conducted a systematic review ($k = 57$) of educational digital storytelling. Their study identified five major educational digital storytelling orientations: appropriative, agentive, reflective, reconstructive, and reflexive. Among these, the most prevalent orientation is appropriative ($k = 35$), which means emphasizing comprehension of learning through the digital storytelling process.

Cognitive Benefits. The simple definition of digital storytelling, offered by Alexander (2017), is to use digital technologies to tell stories and form narratives made from the material of cyberculture. In education, digital storytelling involves using digital tools and multimedia elements, such as images, audio, and video, to craft and deliver learning content that captivates and connects with learners. This pedagogy transcends disciplines, harnessing narratives as a medium to influence the process of knowledge development (Benmayor, 2008; Clarke, 2017; Robin, 2008). Many researchers have found that integrating digital storytelling into teaching not only assists students in retaining new information but also facilitates the comprehension of challenging content (Robin, 2008). From a cognitive

psychology perspective, Egan (1986) proposed that storytelling stimulates children's imagination, allowing them to mentally simulate experiences, explore various possibilities, and engage in creative thinking. More recently, Lucko (2019) pointed out that storytelling functions as a cognitive reframing tool, enabling students to construct compelling counter-narratives that bolster their positive self-awareness.

Emotional Benefits. In addition to enhancing cognitive outcomes, digital storytelling may have beneficial affective and attitudinal outcomes for students. Robin's (2008) study indicated that digital storytelling carries emotional weight and holds personal meaning for both the author and the learner. More recently, Happell and Bennett (2016) have indicated that storytelling infuses humanity into learning experiences, enriching students' capacity to fathom these experiences from a personal and empathetic standpoint.

Authentic Learning

Authentic learning, an educational approach grounded in the concept of situated cognition, emphasizes applying knowledge and skills through real-world, relevant tasks to prepare students for future roles and responsibilities, suggesting that learning is most effective when contextualized within its intended application environment (Herrington et al., 2014). A key affordance of authentic learning is that it both enhances cognitive engagement and promotes active learning (Czerkawski & Berti, 2021; Lampropoulos et al., 2022; Wen, 2020), emphasizing the importance of engaging students in meaningful activities and tasks built around genuine problems and projects from the real world. Such engagement underscores the significance of learning in authentic settings and through hands-on experiences that mirror the complexities and challenges of real-life situations, enabling students to develop practical skills and knowledge (Herrington et al., 2014; Merriënboer et al., 2003). Further, authentic learning should be understood as a curriculum design model rather than a learning theory, focusing on aligning the conditions and facilitators for learning, and drawing from the cognitive apprenticeship model (Herrington, 2015). Authentic learning is also described as situated cognition or situated learning. As suggested by Brown et al. (1989), such knowledge is co-produced through situated activities–structured by context and progressively developed by use: "Authentic activity, as we have argued, is important for learners, because it is the only way they gain access to the standpoint that enables practitioners to act meaningfully and purposefully" (Brown et al., 1989, p. 310).

Further, authentic learning places a significant emphasis on student autonomy and self-directed learning, empowering individuals to take control of their educational paths, and aligning their pursuits with their unique interests, needs, and objectives (Rule, 2016). As Herrington et al. (2009) have noted, authentic learning frequently entails interdisciplinary connections because real-world challenges invariably demand skills and knowledge from a variety of domains. In essence, authentic learning cultivates engagement, serves as a potent motivator for students, and acts as a bridge between the classroom and the real world—all contributing to fostering meaningful learning.

AR and Authentic Learning

In general, AR immersion means integrating digital information with the user's physical environment in real-time, creating a seamless interactive experience. Unlike virtual reality

(VR), which replaces the real world with a simulated one, AR enhances the real world by overlaying it with digital content such as images, sounds, and text. This blending of digital elements with the real world engages the senses and emotions, making the user feel more involved and present in the augmented experience. The immersion in AR is about enriching the perception of reality, thereby making the interaction with digital content feel more natural and intuitive.

AR supports authentic learning by facilitating authentic inquiry, activating observation, and delivering spatial context (Dunleavy & Dede, 2014; Goff et al., 2020; Skulmowski et al., 2016; Wasko, 2013). According to Dunleavy and Dede (2014), the claim that AR as a technology enhances learning is grounded in two theoretical frameworks: 1) constructivist learning theories, which emphasize that individuals build new knowledge through engaging with new information that interacts with their existing knowledge and experiences within a given social context, and 2) situated authentic learning theory, which underscores that meaningful learning occurs through direct interactions with people, objects, places, processes, and culture. Several studies have examined the potential of AR in education, highlighting its ability to enhance learning experiences and create authentic environments. Alkhattabi (2017) has discussed the benefits of using AR in primary school education. His study emphasized the immersive and realistic experiences AR can provide students, making it a valuable tool for authentic learning. Costa et al.'s (2020) study focused on designing a mobile AR platform with game-based learning purposes, highlighting the affordances of AR technology-enhanced authentic practice-based learning activities in promoting student engagement and learning.

For a specific subject such as mathematics, both Fernández-Enríquez and Delgado's (2020) and Rossano et al.'s (2020) studies explained how AR helped students visualize geometry practically, which goes beyond formulaic calculations for areas and volumes. The immersive AR delivers abstract mathematical concepts in a context that students can see and interact with, inherently embodying the essence of authentic learning. AR demonstrably assisted students in acquiring spatial skills by replicating real-world geometric shapes in 3D, thereby making the learning of mathematics through AR an authentic experience. Such studies align with Herrington et al.'s (2014) definition of authentic learning as hands-on, experiential, and aimed at deepening understanding.

Yet traditional teaching methods fall short of offering such authentic experiential learning opportunities. There is a noticeable gap between current research that acknowledges the immersive and multisensory capabilities of AR as pivotal in enhancing educational experiences, and literature specifically addressing how AR, grounded in authentic learning theory, can be effectively integrated into a digital storytelling pedagogy. This oversight is particularly evident in the context of instructional design, where the potential for AR to synergize with the narrative power of storytelling remains largely unexplored. As Dunleavy and Dede (2014) point out,

> *Interactive media now enable various degrees of digital immersion. The more a virtual immersive experience is based on design strategies that combine actional, symbolic, and sensory factors, the greater the participants' suspension of disbelief that she or he is "inside" a digitally enhanced setting. (p.736)*

The essence of their argument—the suspension of disbelief—transforms learning experiences by pulling the audience into a story. To achieve this, AR's immersive features must be meaningfully integrated with storytelling pedagogy. Analyzing AR's effectiveness post-use is the approach most studies have taken; however, studies should also focus on integrating AR in instructional design grounded in educational learning theories, ensuring that AR's capabilities are optimally connected to learning objectives and best design principles for achieving such integration (Zhang & Wang, 2021). A comprehensive AR-enhanced framework for digital storytelling offers an opportunity to transcend traditional narrative approaches and create a situated learning context where learners are not mere observers but active participants in the story. The proposed framework seeks to fill this gap by outlining a structured methodology for combining AR's multisensory capabilities with digital storytelling, aligned with the principles of authentic learning, to transform and elevate the learning experience.

AR-based Storytelling: Concept and Case Study

Concept

Barab et al. (2000) underscored a significant challenge in instructional design: developing learning environments that incorporate authentic tasks within realistic contexts. In alignment with this goal, the proposed AR-based storytelling framework explores the implementation of AR as a tool to promote authentic learning, intertwining it with the pedagogical approach of storytelling. This integration is not just about leveraging AR's technology but also about harnessing its unique characteristics—such as creating a psychologically immersive experience—to transform storytelling into a dynamic, interactive learning process. Echoing Dede's (2005) perspective, in which "interfaces for ubiquitous computing, in which digital technology mobile wireless devices infuse virtual resources as we move through the real world 'pave the way for' rich nodes of site-based gaming and storytelling" (p. 8) in AR development, we envision a learning paradigm where virtual and real-world resources coalesce, enriching the educational narrative and learner engagement.

To establish a foundation for an AR-based storytelling framework, I integrated Herrington and Oliver's (2000) nine essential elements of authentic learning. I chose to base the framework entirely on these nine elements because their abilities to create immersive, engaging, and context-rich learning environments align closely with the strengths of AR technology. These elements also form the backbone of instructional design for effective AR-based storytelling experiences, ensuring that the AR intervention is not merely supplementary but central to the authentic learning process. Moreover, these elements are fundamental in transforming digital storytelling through AR into an effective tool for facilitating authentic learning experiences.

Case Study

The AR Bee App, an AR application previously utilized as part of an interactive exhibit for a science museum (Wang, 2023) was selected as a case study to demonstrate the

possibilities of an AR-based storytelling framework that integrates Herrington and Oliver's (2000) essential components of authentic learning. As a practical application of the framework, this case demonstrates how AR storytelling can be woven into lesson plans, providing students with an engaging and multisensory narrative experience.

In a natural environment, students may not have the opportunity to encounter bees and beehives. Even if they do encounter bees, close observation is often obstructed by the fear of stings. The AR Bee App bridges this gap by allowing students to interact with various 3D bee models within the app. This interaction enables them to identify different types of bees and closely examine their distinct shapes and characteristics. Additionally, the app provides a detailed view of a beehive, which is typically inaccessible in nature.

AR enhances the learning experience by merging digital information with real-world surroundings, promoting authentic learning activities. For instance, one such activity involves students telling stories with AR-generated 3D animated bees placed in natural settings. These narratives can highlight specific flowers that attract different bee species, thereby visually exploring the relationship between bees and the ecosystem (see Figure 1).

By interacting with the AR Bee App in natural settings, students bridge the theoretical and practical aspects of learning. This immersive experience deepens their understanding of bees and their crucial role in the ecosystem, demonstrating the power of AR in facilitating authentic, engaging learning through storytelling.

Figure 1

AR Bee App

Table 1 below is an instructional design framework for authentic learning with AR storytelling. It describes the operationalization of AR multimedia elements within the AR Bee App in facilitating storytelling creation, which exemplifies the framework's capacity to create an authentic context and provide authentic activities with real-world relevance, such as crafting narratives around bee conservation and integrating interactive graphics and video clips to convey messages. The framework highlights the creation of narratives that not only convey information but also encourage students to act and immerse themselves as experts, echoing the sentiment that "emerging technologies provide a lot of opportunities for learners to act as an expert to solve problems and share the narratives and stories through creating learning context or communities" (Huang & Bhagat, 2018, p. 10).

Table 1

Proposed instructional design framework for authentic learning with AR storytelling

Key elements of authentic learning	AR storytelling for authentic learning activities

from Herrington and Oliver (2000)	
Element 1: Provide authentic context that reflects the way the knowledge will be used in real-life **Guideline:** A physical environment that reflects the way the knowledge will ultimately be used	**AR activities:** Students use AR to simulate beekeeping within nature. AR elements are embedded in the story recording to show the process of setting up beehives, managing colonies, and harvesting honey. **Rationale**: AR allows students to interact with digital elements overlaid with their physical environment, creating a blended space where learning activities can take place within the context of the real world. This is particularly effective for storytelling, as it grounds the narrative in a tangible setting, making the learning experience more relevant and meaningful (Lee & Park, 2020; Dunleavy & Dede, 2014). **Feature of AR storytelling**: It provides immersive learning by accessing real-world contexts, making the story more compelling, helping students feel more connected to the narrative, and enhancing the overall storytelling experience.
Element 2: Provide authentic activities **Guideline**: Activities which have real-world relevance	**AR activities**: In a nature park, students use AR to create narratives that highlight the importance of bee conservation by pointing to flowers or plants. They can integrate AR elements into their stories, such as interactive graphics or video clips, to convey messages. **Rationale:** The use of AR in storytelling allows for creative expression in ways that traditional storytelling methods may not. Students can experiment with different scenarios and digital elements, which can lead to innovative and personalized stories (Nordmark & Milrad, 2012; Lohnes Watulak, 2018). **Feature of AR storytelling:** It integrates digital elements with the physical world to create a blended reality, encouraging students to actively participate and make decisions that affect the narrative, allowing the story to unfold in real time.
Element 3: Accessing expert performances and modeling of processes **Guideline**: Opportunity for the sharing of narratives and stories	**AR activities**: Students access AR storytelling in a nature park. Using an AR app, they view segments of a narrative created by entomologists about bee ecology based on points of interest along the trail. **Rationale**: “Emerging technologies provide a lot of opportunities for learners to act as an expert to solve problems and share the narratives and stories through creating learning context or communities” (Huang & Bhagat, 2018, p. 10) **Feature of AR storytelling**: It brings expert insights into the storytelling experience without the constraints of time and physical location, making the storytelling more aspirational.
Element 4: Provide multiple roles and	**AR activities**: From the teacher’s perspective, students use the AR App to develop simple, illustrated stories or digital picture

perspectives **Guideline:** Different perspectives on the topics from various points of view	books that explain the role of bees in nature, designed to be shared with younger audiences. **Rationale:** Storytelling in AR can recreate any event, allowing students to experience and understand the event from different perspectives (Tenh & Shiratuddin, 2022). **Feature of AR storytelling**: It incorporates game-like activities, including role-playing to step into the shoes of characters within the story, building a deeper connection to the narrative and a better understanding of different perspectives and scenarios.
Element 5: Support collaborative construction of knowledge **Guideline:** Tasks that are addressed to a group rather than an individual	**AR activities:** Students use AR to collaboratively create a bee-themed story together, adding digital elements to the physical environment to co- construct knowledge about bees' behaviors and habitats. **Rationale:** AR storytelling often involves collaboration, as students may work together to create and share stories. This social aspect of learning through AR can enhance communication skills and foster a sense of community among learners (Nordmark & Milrad, 2012; Maya et al., 2022). **Feature of AR storytelling**: It enables multiple users to interact with the same digital content simultaneously so that storytelling becomes a shared experience where students can collaborate, discuss, and explore the narrative together.
Element 6: Promote reflection to enable abstractions to be formed **Guideline:** The opportunity for learners to compare themselves with experts	**AR activities:** Students record the story about their observations of bees in the park through an AR app. AR overlays prompt reflections on bee behaviors, preferred flowers, and environmental factors, delivering a tangible experience that makes the invisible visible. **Rationale:** Every story is interconnected, displaying intertextuality between its internal narrative and the external world. AR transforms stories into a tangible experience by personalizing them through the meaningful connections people situated with real-world surroundings (Alexander, 2017). **Feature of AR storytelling**: It helps to visualize abstract content through immersive learning experiences that transform abstract content into tangible, interactive elements within the story, making the story more vivid and relatable.
Element 7: Promote articulation to enable tacit knowledge to be made explicit **Guideline:** A complex task incorporating inherent, as opposed to	**AR activities:** Students use AR to film or photograph various bee-related scenes in the park, such as bees pollinating flowers or constructing hives. Added interactive AR animated bees, annotations, or narration explain the significance of each scene, thereby externalizing their tacit understanding of bee interactions.

constructed, opportunities to articulate	**Rationale:** The “exocentric” frame of reference provides a view of an object, space, or phenomenon from the outside, while the “egocentric” frame of reference provides a view from within the object, space, or phenomenon. The exocentric and the egocentric perspectives were found to have different strengths for learning, and the “bicentric” perspective alternating between egocentric and exocentric views was shown to be particularly powerful. (Dunleavy & Dede, 2014) **Feature of AR storytelling:** It enables exocentric views to provide a broad context and understanding of the environment and interactions within the story, while egocentric views allow for detailed, personal engagement with specific elements of the narrative.
Element 8: Provide coaching by the teacher at critical times, and scaffolding and fading of teacher support **Guideline:** Teacher implementing program for coaching and scaffolding assistance to learners	**AR activities:** Teachers create AR-guided tours within the nature park, highlighting specific areas relevant to bee ecology. Using AR overlays, students learn about bee habitats and pollination processes. This immersive learning experience assists students in understanding the importance of bees in maintaining biodiversity. **Rationale**: Engagement in learning was significantly high using technology-mediated narratives, interactive experiences, situated contexts, and collaborative problem-solving offered within AR simulations (Tang et al., 2020). **Feature of AR storytelling:** It provides real-time feedback to reinforce learning by helping students apply concepts correctly in real time, solidifying their knowledge through practice and repetition within the narrative context.
Element 9: Provide for integrated assessment of learning within the tasks **Guideline:** Fidelity of context	**AR activities:** Students use the AR app to create an interactive exhibit in the park illustrating the life cycle of bees. They create overlaying content to showcase each life stage to talk about the transformative journey of bees, demonstrating students' knowledge of bee life cycles. **Rationale:** AR helps students connect their learning to real-life situations by situating digital stories in real-world contexts. This contextualization makes the content more relevant and meaningful, which is a key aspect of authentic learning (O’dwyer et al., 2021). **Feature of AR storytelling**: It situates assessments with the real-world context to provide authenticity of the narratives and the tasks involved.

By crafting AR trails in nature parks, students engage with various perspectives on bee ecology, constructing knowledge collaboratively, which is vital for fostering a learning community (Normand & Millard, 2012; Maya et al., 2022). Furthermore, the AR Bee App supports reflective and articulated learning by enabling students to record and share

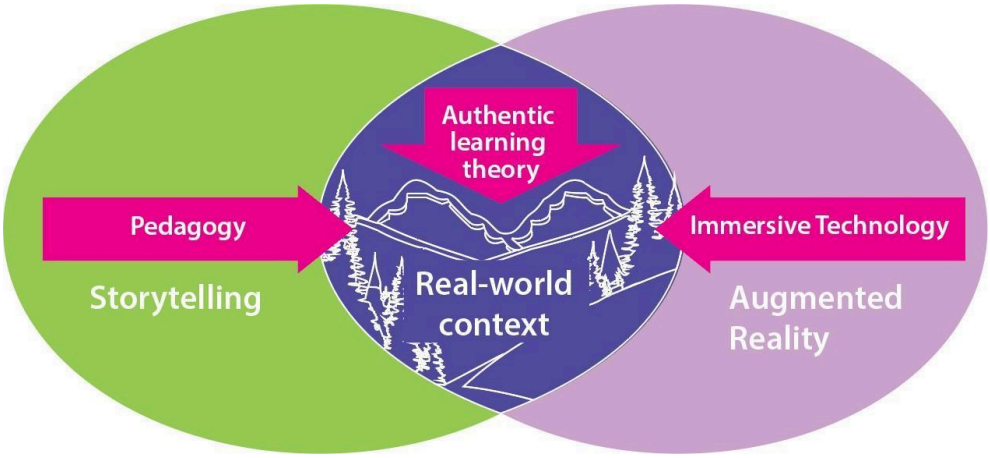
observations, thus promoting the comparison of their experiences with other learners and experts. This form of augmented learning also aids in making tacit knowledge explicit through filming or photographing bees in their natural habitats, with AR overlays providing additional context and explanations. Critical to this framework is the fidelity of the learning context. The AR Bee App allows students to assess and interact meaningfully with the bee life cycle, drawing a powerful connection between theoretical knowledge and tangible experiences in the real world. By offering these affordances, the framework not only adheres to the theoretical underpinnings of authentic learning but also leverages the immersive quality of AR to create a pedagogically sound and engaging storytelling journey.

Centring Authority: Findings and Possibilities

Integrating AR with digital storytelling, grounded in authentic learning principles, broadens the research field on immersive technology that facilitates learning and fosters connections with the real world. The framework presented in Table 1 illuminates this by aligning the key elements of authentic learning, as defined by Herrington and Oliver (2000), with features of AR storytelling, revealing a multifaceted approach to instructional design. The core of this intersection is the principle of authenticity (see Figure 2).

Figure 2

AR-based Storytelling



AR immersion for a deeper connection with stories

A meaningful story requires an understanding of the context and enables personal experiences and connections rather than passive observation and narration. AR enables students to synergize digital learning objects with real-world content, translating abstract or complex concepts into more comprehensible and applicable ones. The AR Bee App showcases how to utilize multimedia features to create authentic learning that allows for a deeper connection with the subject of study. Integrating this app with the proposed

instructional framework demonstrates the potential of AR to facilitate the creation of stories in a contextualized manner, saturating them with depth and meaningful connections. Transcending traditional classroom boundaries, learners engage with bee ecology in a context that mirrors actual ecosystems: not just about simulating real-world tasks but immersing students in them.

AR immersion for interactive stories

Newmann et al. (1996) argued that learning is achieved by not only transmitting information to students, who passively replicate what's given, but by active engagement wherein students interact with, process, interpret, and negotiate the information they encounter through their personal experience and social interaction. The AR technology for storytelling is an innovative approach to transforming how learners engage with content and immerse themselves in dynamic, interactive narratives. It also aligns with Papert's (1980) concept of "objects-to- think-with," which emphasizes the importance of physical and digital objects, tools, or materials that serve as cognitive aids or mediums for thinking and learning. When AR is used for storytelling, it serves not merely as an instructional tool but also as an interactive entity that learners can manipulate and explore to create stories in a blended space: that is, digital and physical surroundings.

AR immersion for collaborative stories

Dunleavy and Dede's (2014) study underscores the significant role of AR in offering a collaborative and multifaceted learning experience. Their study reveals that AR's notable capability lies in providing learners with diverse yet complementary perspectives about a problem situated within a physical space. This capacity of AR aligns seamlessly with the collaborative nature of storytelling, enabling multiple users to access and contribute to a story simultaneously. Within this shared AR environment, each learner encounters different AR-enhanced elements, offering unique perspectives that contribute to the richness of the collective stories. Thereby, stories transcend book pages or digital screens, fostering a learning community where knowledge becomes an enriched collective asset.

AR immersion for multisensory stories

Digital storytelling through AR is vivid, interactive, and dynamic because stories can be presented that include sound, animation, sensor movement, sight, hands-on interaction, and even smell. The rich multimedia elements generated by AR make this form of storytelling pedagogy unique. For example, hands-on engagement with 3D animated bees enables students to weave more informed, empathetic narratives that reflect a deeper understanding of the subject (Wang, 2023). As they interact with AR virtual elements, learners can craft stories that are not only factually accurate but also emotionally resonant with the world of bees. Further, powerful digital storytelling involves a holistic exploration of the interplay among technology, ecology, culture, and human experience, and AR can assist in achieving this. Indeed, Kumpulainen et al.'s (2023) study indicated that AR storytelling "builds from and cultivates empathy for both humans and nonhumans, generating possibilities for technical and communal solutions, sensitizing participants to cultural traditions, and creating rich aesthetic and embodied responses to natural and cultural landscapes" (p.34). A sensory-rich, immersive experience through an AR platform allows students to form stronger mental

associations, recall information more easily, and develop higher-order skills (Li et al., 2022; Markouzis & Fessakis, 2016). For these reasons, AR storytelling offers a multisensory experience that uniquely captivates and immerses learners.

Challenges to integrating AR

Despite AR holds potential to enhance digital storytelling, its widespread implementation in classrooms has been limited, partly due to the challenges faced by instructional designers and educators. There is a need for more empirical studies grounded in educational theories to provide evidence-based instructional design principles for AR. Such principles can guide instructional designers in identifying which AR multimedia elements are effective in enhancing learning. Additionally, these principles can help educators make informed decisions about utilizing AR into their lesson plans, ensuring that its integration is both strategic and beneficial to the learning objectives. Moreover, providing educators with the training is essential to leverage AR's full potential in teaching and learning. Our exploration should not be limited to how to implement AR in line with learning theories. It is equally important to investigate when AR should be integrated during the learning process for better impact, and to identify what the specific learning outcomes are.

Conclusion and Future Directions

This paper presents a case study of a practical, hands-on framework for integrating AR storytelling with authentic learning instructional design. Through demonstrating AR storytelling activities within the framework, students are empowered to incorporate multimedia digital elements, including 3D objects, animations, and games, into their narrative creation. This enrichment not only applies to students recording their explorations and experiments in the natural environment but also extends to encompass content creation processes inherent in storytelling. Furthermore, the narrative experience transcends the traditional observer's standpoint, allowing students to assume diverse roles and perspectives. They can actively participate in the storytelling process, presenting their stories in an immersive manner devoid of temporal and spatial constraints.

The educational paradigm is evolving rapidly to accommodate the young generation of learners, who favour active knowledge construction through digital technologies. These learners navigate multiple media streams with ease, collaborate to synthesize diverse experiences and seek learning environments that are active, reflective, and personalized. AR technology is particularly well-suited to meet these needs, offering new dimensions of engagement and interactivity.

This study is designed to foster a learning environment where authenticity and immersion integrate to facilitate learning. As we advance our understanding of AR in educational settings, it is imperative to acknowledge the changing nature of students and the corresponding need for educators to adapt. Dede (2005) asserts, "As the nature of students alters, instructors must themselves experience mediated immersion and develop neomillennial[sic] learning styles to continue effective teaching" (p. 11). The proposed framework contributes to this development by offering a structured approach to integrating

AR into storytelling, highlighting its potential to transform learning experiences that resonate with contemporary students.

To build on the insights gained from this study, future research should include comparative studies to further examine the efficacy of AR storytelling. Such explorations would provide valuable empirical data on the benefits and challenges of integrating AR in education, informing best practices and guiding future pedagogical strategies. Clearly, the potential of AR to revolutionize storytelling and create immersive, authentic learning experiences is substantial.

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