

Challenges associated with using AR technology in education

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Abstract

As commonly understood, Augmented Reality (AR) technology, with its potential to blend digital content into the real world, has gained significant attention in various fields. However, its implementation is not without hurdles. Embracing AR comes with a set of challenges that cover technical, usability, ethical, and practical considerations. It may happen that the augmentation doesn't consistently yield the desired outcomes, work as initially intended, or deliver a seamless and satisfying user experience. In this article, we present the standards in the development and adoption of AR, also solutions to enhance augmented experiences based on our two years of developing educational applications.

Keywords: Augmented reality, artifacts, challenges.

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1 Introduction

Augmented reality integration within the realm of education offers students the opportunity to engage in immersive experiences, thereby enhancing the learning process by making it more interactive, efficient, and meaningful. Augmented reality services within the educational and training domain empower users to interact with real-time applications and virtual elements that elucidate and illustrate concepts using multimedia, computer-based simulations, animations, quizzes, etc. This mode of augmented reality education effectively supplements conventional teaching and learning methodologies by fostering critical thinking, elevating student engagement, and enhancing their comprehension.

However, this augmentation doesn't consistently yield the desired outcomes, work as initially intended, or deliver a seamless and satisfying user experience. Various challenges and issues can arise [3] when working with augmented reality methods.

We consider that augmented learning is a personalized learning approach that adjusts to the needs of the learner. It offers real-time remediation to help learners better comprehend a subject, encouraging exploration and understanding [5]. This approach leverages technologies that incorporate multimedia and interaction, which researchers, teachers, pupils [6], and students [4] have enthusiastically embraced. Instead of emphasizing rote memorization, learners engage in an adaptive learning process that responds to their immediate context. Augmented content can dynamically adapt to the learner's surroundings and learning styles by presenting text, images, videos, or even audio, such as music or speech. Typically, this additional information is displayed through pop-up windows in computer-based environments.

Over the past two years, we have been actively exploring novel techniques and strategies for integrating augmented reality into educational settings. Drawing from our personal experiences of both setbacks and achievements, we have accumulated valuable insights that we are eager to share in this paper.

2 Standards in AR

First of all, an important point is about the role of standards in the development and adoption of emerging technologies like Augmented Reality (AR). Standards play a crucial role in ensuring interoperability, compatibility, and the overall development and acceptance of a technology. Here are some key insights and considerations regarding standards in AR:

1. **Early stage challenges:** AR is still in its relatively early stages of development, with both hardware and software evolving rapidly. This dynamic environment makes it challenging to establish concrete standards when the technology is still evolving and there isn't yet a clear consensus on what those standards

should be.

2. **Interoperability and compatibility:** Without standards, AR applications and devices may not work seamlessly with each other. This can hinder user experiences and limit the broader adoption of AR technology. Standardization can ensure that different AR devices and software can communicate effectively.
3. **Innovation vs. standardization:** There is often a tension between rapid innovation and the establishment of standards. Early on, the focus is on experimentation and pushing the boundaries of what's possible. Standardization can sometimes slow down this process. However, once the technology matures, standards become essential for widespread adoption.
4. **Industry collaboration:** The development of AR standards typically involves collaboration among industry stakeholders, including hardware manufacturers, software developers, and content creators. Various organizations, such as the Open AR Cloud, IEEE, and W3C, work on defining standards and best practices in the AR space.
5. **User privacy and security:** AR standards should also address privacy and security concerns, as AR involves real-world interaction and data collection. Setting standards for data privacy, security, and user consent is critical for ensuring the ethical use of AR.
6. **Consumer trust:** The lack of standards can create uncertainty and consumer hesitancy. When consumers don't know what to expect from an AR experience, they may be less likely to embrace the technology. Standards can help build trust and confidence in AR applications.
7. **Regulatory considerations:** As AR becomes more widespread, governments and regulatory bodies may step in to establish their own standards and guidelines for the technology, particularly in areas related to safety and public use. In our country this field is pretty new, so there are still no such regulations related to AR.

8. **Evolution of standards:** AR standards are likely to evolve over time as the technology matures. They may start with basic interoperability and compatibility standards and gradually expand to cover more aspects of AR, such as content creation, user interfaces, and hardware specifications.

While the absence of comprehensive AR standards is a current challenge, it's a natural part of the technology's early development. As AR technology continues to grow, it's expected that industry collaboration and evolving standards will contribute to its broader adoption and the creation of a more unified AR ecosystem. These standards will not only benefit developers and businesses but also provide a better, more consistent experience for AR users. In the next section, we'll present a few challenges and issues related to designing augmented markers and creating an augmented experience in itself.

3 Challenges and issues in creating augmented reality experiences

The integration of augmentation technology within the education field holds the promise of transforming the learning process for students, but it comes with its set of challenges. As this technology becomes increasingly accessible and sophisticated, it is crucial to contemplate the ramifications for educators and students. One of the most significant hurdles is the cost, as this technology can be prohibitively expensive, and educational institutions often operate within tight budgets. According to research [7], they organized interviews and the results shed light on several challenges associated with the implementation of handheld AR technology among school teachers. The primary obstacle identified was the lack of a universal Bring Your Own Device (BYOD) policy in primary schools. Some participants reported that their schools did not permit students to bring digital devices, and only a small percentage mentioned financial constraints among parents as a reason for this restriction. Concerns were raised by both parents and school administrators about the potential loss of students' devices, leading to a reluctance to allow personal devices in classrooms. Some

teachers expressed a preference for the school providing handheld devices in a controlled environment, such as a lab, to facilitate efficient use of AR for educational purposes.

Nevertheless, it is essential to weigh these initial costs against the potential long-term benefits of such investments.

Another challenge is the need for teachers to become proficient in using this technology to its fullest extent. Some of them may face troubles and require additional support to effectively utilize the technology. According to [8], numerous challenges have been identified in teachers' adoption of Augmented Reality. These challenges encompass the difficulty in delivering sensory-rich instruction, constrained class time, a limited understanding of AR technology, apprehension about potential technological setbacks, a shortage of necessary equipment, high associated costs, and inadequate training for handling technological tools. Additionally, teachers may harbor misconceptions about the utility of AR tools, leading to a lack of reliance on this technology, further impeding its integration into the teaching process. There exists a general lack of familiarity among teachers with AR technology, making them less inclined to engage in ad-hoc developments due to affordability concerns. The unawareness of effective strategies to enhance student learning motivation using AR tools is another challenge faced by teachers.

Additionally, teachers must remain vigilant regarding potential risks, including cybercrime and data security breaches that could arise from the use of human augmentation technology in the classroom.

Nevertheless, the most significant challenge lies in the development of augmented content itself. In our application's development, which relies on marker-based technology, we encountered the issues described in the following subsections.

3.1 Challenges related to markers and artifacts

We consider markers to be the digital image of a trigger, and the physical one is called an artifact. According to [1], markers with ratings of 2-3 stars can pose problems during the recognition and tracking phases. Vuforia Engine relies on the grayscale version of markers to

identify features for recognition and tracking. If the image exhibits low overall contrast and a narrow, spiky histogram, it is unlikely to function effectively as a target image. In our initial set of markers, which were designed using black and white colors, markers received ratings of 2-3 stars after evaluation. As a response to these challenges, we addressed the issues by introducing color and additional features in the second batch of markers, consequently increasing their rating to 4-5 stars. Another set of challenges arose due to the similarity in marker designs, leading to confusion for AR cameras, as shown in Figure 1.

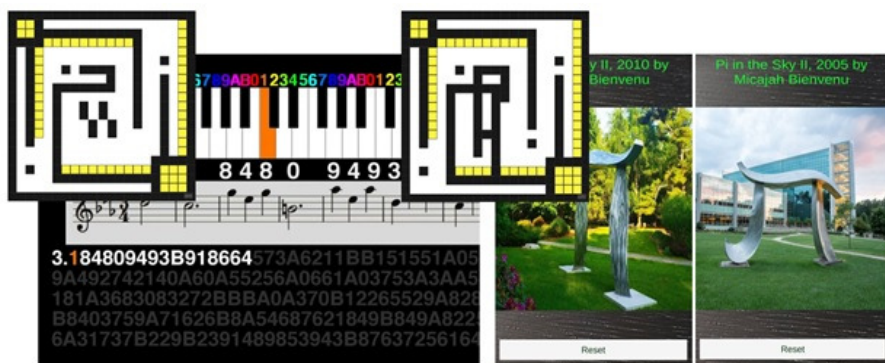


Figure 1. Example of similar markers that are confused

The left marker corresponds to the Pi Symphony augmentation experience, while the right marker randomly triggers the visualization of Pi in the Sky artworks by Micajah Bienvenu [2]. When using either one of these markers individually, AR cameras correctly identify and track the actions with 100% accuracy. However, when the markers were scanned sequentially, AR cameras triggered both marker scenarios simultaneously.

3.2 Challenges related to augmented learning content

A notable challenge pertains to the diversity of content to accommodate various learning styles and adhere to Bartle's Taxonomy. In order to provide students with personalized content that enables them to

learn more effectively, easily, and thoroughly through active engagement, it's imperative to identify areas for improvement. This entails affording students the opportunity to participate in refining the educational content and expressing both positive and negative feedback.

In this context, we conducted an experiment involving students from "Aleco Russo" University in Balti. The experiment involved providing participants with artifacts and mobile applications. Their objective was to test each artifact, which contained various types of augmented scenarios. Subsequently, we granted access to an online survey to gather information. The survey included questions related to the design of the artifacts, the augmented reality learning content, and the performance of the application itself. We collected data on the application's functionality, user satisfaction, and received recommendations for potential improvements. For example, some recommendations related to augmented scenarios are presented in Figure 2.

3.3 Challenges related to augmented scenarios

Last year, we showcased some of our augmented artifacts at the International Exhibition of Creativity and Innovation, known as Excellent IDEA, which was organized by the Innovation and Technological Transfer Center of ASEM. During this exhibition, we received valuable recommendations for enhancing our scenarios. One particular scenario involved the creation of augmented artifacts for children with disabilities who were attending a children's camp. In this scenario, we aimed to provide an interactive experience showcasing 3D models of both wild and domestic animals along with their associated sounds, as shown in Figure 2 (Wolf v1.0). Subsequently, when we presented this augmented scenario to students from Aleco Russo University, they expressed interest, but they found it to be relatively straightforward. Their feedback prompted us to elevate the complexity of the scenario by introducing features that required user interaction with the 3D model. As a result, we incorporated four buttons that allowed the wolf to perform actions such as running, howling, lying down, and fighting, as depicted in Figure 2 (Wolf v2.0). Each action is followed by a sound.



Figure 2. Example of improved scenario

4 Improvements of augmented reality experiences, solutions

Designing augmented markers and creating compelling augmented experiences come with their own set of challenges and considerations. Here are some summaries of the key challenges, issues, and solutions related to these aspects of augmented reality.

Marker design and recognition: Designing markers that are easily recognizable by AR systems while blending seamlessly into the physical environment can be challenging. Complex or cluttered markers may lead to recognition errors.

Solution: AR artifacts should be designed with clarity and intuitiveness in mind. Users should be able to understand the purpose and functionality of an artifact at first glance. The design should provide visual cues or information to guide users. If certain artifacts are not immediately intuitive, consider incorporating educational elements or tooltips to provide users with guidance on how to interact with them effectively. For example, adding quiz icons for artifacts that contain quizzes.

Environmental variability: AR systems can be sensitive to changes in lighting conditions. Creating markers and experiences that work well in various lighting environments, including low light and out-

door settings, can be a challenge. Our second version of artifacts was laminated with a glossy finish because it makes colors appear more saturated and imparts a professional and refined appearance. Moreover, glossy laminates excel in concealing fingerprints and smudges, simplifying the task of maintaining cleanliness. However, because of the highly reflective aspect, the AR experiences were difficult to recognize.

Solution: When it comes to laminating artifacts, a matte finish is the preferred choice. It effectively minimizes reflective light, and though it may slightly reduce color vibrancy, it maintains a subtle tactile quality that exudes professionalism. Although matte finish offers less protection compared to gloss and can show scratches and fingerprints, it doesn't pose concerns during recognition and tracking processes.

User experience: Ensuring that AR experiences are engaging and valuable to users is essential. It's crucial to strike a balance between the novelty of AR and the practicality of the experience.

Solution: One approach to achieve this balance is to actively engage teachers in the design of AR scenarios. Their input can help craft more effective and beneficial experiences that cater to educational needs.

Content Creation: Creating high-quality 3D models, animations, and interactive elements for AR experiences can be resource-intensive and require expertise in 3D design and development.

Solution: To enhance the quality and effectiveness of content, one effective solution is to enlist the services of a skilled designer, despite the potential cost involved. Alternatively, you can create your own 3D models and animations, which may be time-consuming but cost-effective. In our cases, we used free 3D models from Unity Assets.

User interface (UI) design: Designing user interfaces for AR experiences that are intuitive, non-intrusive, and accessible can be a complex task. The UI should complement the augmented content and not overwhelm users.

Solution: To address this challenge, we adopt a minimalist approach, striving for simplicity. Each artifact is dedicated to a single task or lesson, presenting information in manageable chunks. Additionally, for AR scenarios that involve user interaction during movement,

the design of artifacts is tailored to adapt to user actions, ensuring interaction without causing confusion.

Tracking and calibration: Accurate tracking and calibration are essential for a seamless AR experience. Maintaining the alignment of virtual objects with the physical environment, especially in dynamic situations, can be challenging.

Solution: Implement computer vision algorithms to improve object recognition and tracking accuracy. Feature detection, optical flow, and SLAM (Simultaneous Localization and Mapping) techniques can enhance real-time tracking. It is also possible to integrate machine learning algorithms to predict and compensate for potential inaccuracies in tracking. This can enhance the system's ability to adapt to various environments and user movements.

Integration with real-world objects: Incorporating real-world objects into AR experiences, like recognizing and interacting with specific physical objects, can be technically challenging due to variances in object appearance and shape.

Solution: Implement techniques such as feature detection, image matching, and deep learning to improve object recognition capabilities. Also can be created 3D models of real-world objects through scanning technologies (like photogrammetry or structured light scanning) to facilitate accurate digital overlays and interactions.

Device accessibility and affordability: One of the primary hurdles in integrating AR into education lies in the technology's technical prerequisites and constraints. For instance, AR demands devices like smartphones, tablets, or headsets that need to be both compatible and economically viable for teachers and pupils. The accompanying software, encompassing apps, platforms, or tools, must exhibit reliability, security, and user-friendliness for seamless integration. Moreover, the effectiveness of AR is contingent upon the quality and accessibility of internet connections, the durability of device battery life, and the adequacy of data storage capacity. Addressing these technical intricacies is essential to facilitate widespread and effective implementation of AR in educational settings.

Solutions:

- Governments can implement programs to provide subsidized or

free AR-compatible devices to schools, ensuring that both teachers and students have access to the necessary hardware.

- Schools can allocate budgets specifically for the purchase and maintenance of AR-enabled devices. Collaborations with technology providers may lead to discounted rates for educational institutions.
- Encourage BYOD policies [8] where students can use their personal smartphones or tablets for AR applications, minimizing the burden on schools to provide devices.

Privacy and security: AR apps often require access to a user's camera and potentially other sensors. Addressing privacy concerns and ensuring the secure handling of user data is a critical issue. Moreover, a growing trend involves the adoption of policies permitting students to use their personal devices at school. While this BYOD approach offers economic and operational advantages, it simultaneously introduces potential security vulnerabilities and negative consequences, contingent upon the ethical behavior of students and the absence of robust safeguards within school regulations [9].

Solution: Implement secure communication channels (e.g., SSL/TLS) to protect data integrity during transmission, using robust encryption protocols to prevent unauthorized access or interception, minimize data collection to only essential information required for AR functionality.

Cross-platform compatibility: Developing AR experiences that work seamlessly on multiple AR platforms (e.g., ARKit, ARCore, and various headsets) can be complex due to platform-specific requirements and capabilities.

Solution: Utilize standardized development frameworks like Unity 3D, Unreal Engine, PlugXR or WebXR that offer multiplatform support, allowing developers to create AR applications that work across different devices and operating systems. Conduct thorough testing across a range of devices, operating systems, and AR platforms to identify and address compatibility issues, ensuring a consistent user experience.

Addressing these challenges requires a combination of technical expertise, user-centric design, and a thorough understanding of the capabilities and limitations of AR technology. As AR continues to evolve, these challenges will also evolve, and new solutions will emerge to overcome them.

5 Conclusion

Furthermore, the introduction of human augmentation technology may alter the traditional dynamics of student learning and interaction. For instance, if students rely on augmented reality glasses to access educational content, it could reduce face-to-face interactions. While this technology has the potential to enhance learning outcomes, educators must be mindful of its potential impact on student engagement and socialization. With the introduction and adoption of smartphones and later introduction of Hololens and Oculus Rift, Augmented Reality technology that once seemed a thing of the somewhat distant future became feasible and started to evolve. It took some time to get a grasp on fundamentals but now the development of an augmented reality application is not much of a problem – just a matter of figuring out what’s and why’s.

Based on our two years of developing educational applications, in this article, the standards in the development and adoption of AR, also solutions to enhance augmented experiences were presented.

This paper is the extended and revised version of the conference paper [10] presented at WIIS 2023.

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