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# Applications of augmented reality as a blended learning tool for architectural education

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## ABSTRACT

Augmented reality (AR) is an innovative learning tool that is gaining popularity in educational settings as it has the potential to significantly enhance interactive learning. In addition, AR has been a significant contributor to blended learning because it can be used in addition to conventional learning aids like text, images, video tutorials and the internet. However, there is a lack of research on the application of AR in the context of programmes with technical and practical components particularly with reference to the possibilities it may offer in terms of Architecture, Engineering and Construction (AEC). This paper reports on the first phase of an action research study done in an architecture department in a higher education institution that offers a module on Construction Technology. The learning unit for which AR is particularly explored is Construction Methods, Assembly, and Materials. A qualitative research approach was applied where principles of the Delphi method were used after selecting a group of eight experts who were purposively sampled. The participants were exposed to the AR technology, viewed a simulation, and were encouraged to explore three-dimensional model building for themselves by using the AR tool. Themes that emerged from group discussion were recorded to illustrate the possibilities of the application of AR in the context of the module as well as possible limitations or concerns. Curriculum outcomes were then proposed to enhance an interdisciplinary component, incorporating the AR project outcomes with wider applicability than architecture only. The implications shared should be applicable to skill development in engineering and construction education in learning units that deal with construction methods, assembly and materials.

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## Introduction

Educators often rely on conventional ways to transfer information to learners, which usually entails that the educator instructs learners who are expected to listen and absorb the information shared (Tarling & Ng'ambi, 2016:554). In this regard, new technologies are not necessarily embraced. Tarling and Ng'ambi (2016) developed a pedagogical framework or continuum that clearly shows the need to develop new skills and content to keep up with emerging technologies within an education context. With their framework, these authors explain the importance of sustainable change in terms of various pedagogies "that can and should be used in different contexts to achieve deep and meaningful learning" (Tarling & Ng'ambi, 2016:561). Similarly, Demirkan (2016:28) urges educators to be "forward thinking about how to educate, train and inspire the coming generation" while Venter and van der Wath (2014:1) remind us that there is a shared symbolic relationship between academic and professional environments in that emerging technology skills would need to be fostered in studios if educators want to foster professionals who are competent in these emerging technologies. From this shared wisdom, I note that sustainable educational pedagogies have been promoted over the last decade and such pedagogies will need to promote future-fit learners which necessitates development of skills regarding new technologies.

In recent decades, emerging technology has improved to enhance diverse delivery of education in the sense that interactive methods have been developed, referred to as technology-enhanced learning (TEL) (Demirkan, 2016). Technology-enhanced learning can address many learning challenges and can often blur boundaries within the conventional classroom in terms of the roles that the instructor/teacher and learners play. In this regard, it can promote engaged learners and meaningful learning. Many scholars have reflected on how TEL needs to be re-conceptualised and understood. Augmented reality (AR) falls within the realm of emerging technologies that can foster TEL.

By 2014, Bacca, Baldiris, Fabregat, Graf and Kinshuk (2014) completed a comprehensive study to establish in which disciplines AR research was being done and at which level of education it is being applied. It was reported that only 15,6% of research has been done in engineering, manufacturing, and construction. There was no research reportedly being done in architecture, design, or technology. Most of the research being conducted in educational technology was reported in the fields of science and mathematics at primary, secondary and tertiary education level, with less research applications in humanities and arts, social science, business and law, than other sectors.

Although engineering, manufacturing and construction is the second-most researched discipline, it constitutes a small percentage of the total research undertaken. It is not very clear from the research how much Architecture, Engineering and Construction (AEC) research is constituted within that percentage. In general, it appears as though there is very little AR research in this field (Bacca *et al*, 2014:139).

It is important to frame the purpose of each AR project to be clear what the intended TEL purpose would be. According to Bacca *et al* (2014:140), most AR learning applications address, in diminishing order, “explaining the topic” at 43,75% and “augmenting the topic” at 40% and then educational gaming at 18,75%, while lab experimentation and exploration were the least used (Bacca *et al*, 2014:140). AR in construction technology would fall into the top two categories of explaining the topic as well as augmenting the information. Traditional two-dimensional technical information limits three-dimensional understanding and eclipses important cognitive aspects of complex construction technology and may therefore fulfil the role of explanation of what the students is looking at, the parts to the whole, the form, the structure, its materials, and its assembly.

The aim of this paper is to report on the first phase of an action research study that included an exploration of the application of Augmented reality in AEC in a particular architecture module. The paper commences with a literature review on the constructs relevant to artificial intelligence in order to contextualise the importance of TEL within augmented reality (AR). It then moves on to discuss the methodology and offers findings and conclusions. The implications of AR within education in AEC are offered as final thoughts.

## Literature review

In this review of scholarship, the constructs relevant to the study are explained in order to contextualise the technology that was used in the study and the role of this technology in teaching.

### *Augmented reality as construct*

An acknowledged reality-virtuality continuum indicates the relation between a real environment, augmented reality (AR) and a virtual environment (Bacca *et al*, 2014:133). Essentially, mixed reality is a sliding scale of immersion where, on the one end, the viewer is looking at reality through a device with limited overlays of augmentation or virtual information and, on the other end, where virtual reality is a complete immersion into a digital word with very little or no reality. Generally, researchers use the terms 'superimpose', 'co-exist', or 'combining' to refer to virtual objects in reality (Bacca *et al*, 2014:133). Augmented reality is a dimension on the reality-virtuality continuum (Wang, 2011:510). It is important to note that AR is not the same as a virtual environment, where the user is completely immersed in a synthetic environment, but rather supplements reality (thus not replacing it) (Azuma, 1997:356).

There is no single definition for AR. Attempts to define AR include the notion proposed by Chen and Tsai (2012), who mention that AR allows for interaction with two-dimensional or three-dimensional virtual objects integrated in a real-world environment. In the definition of Chi, Kang and Wang (2013:116), AR is the result of computer-generated information that is superimposed onto the user's view of the real-world scene. Wu, Lee, Chang and Liang (2013:42) have a similar view on AR and highlight in their definition that AR "creates a reality that is enhanced and augmented" while Mendoza-Garrido, Cabarcas-Álvarez, Puello-Beltrán, Fabregat-Gesa and Baldiris-Navarro (2021:53) remind us about AR technology that enables superimposing content with a device by the application of such a device. These views and definitions are discipline-specific and emerge from an information technology perspective. Perhaps Gurevych, Silveistr, Mokliuk, Shaposhnikova, Gordiichuk and Saiapina (2021) offers a view on AR that is more universally applicable with his emphasis on the applicability of AR technology in that AR technology combines science and life when it can be applied to recreate real-life situations or even create fictional spaces for problem solving.

In this study, an expanded view of AR is offered: Dunston and Wang (2011:510) state that "AR allows a user to work in a real world environment while visually receiving additional digitally facilitated information to support the task at hand". This view is applicable in the design realm and links to the former universal view of Gurevych *et al* (2021) on problem solving. Furthermore, the educational context needs to be added. In this regard, the coexistence of virtual objects and real environments allows learners to visualize complex spatial relationships and abstract concepts, experience phenomena that is not possible in the real world, interact with two- and three-dimensional synthetic objects in mixed reality, and develop important practices and literacies that cannot be developed and enacted in other technology-enhanced learning environments (Wu *et al.*, 2013:41).

For this study, the definition is thus that AR is a concept from the emerging technology realm that involves the application of technology that supplements reality where a device is applied, and unseen phenomena can be overlayed and visualised in space that coexists with reality. In this regard, the conceptualisation of AR in this study also allows possibilities for blended learning as it is argued that AR can be used to enhance learning and can be used in classrooms as well as outside the classroom to "blend" the learning experience of a student.

*Emerging technologies in design education*

In particular settings, such as studio educational settings, recent studies have indicated that the use of technology in design studios supports interaction, active learning and social engagement, which are reflected in students' development of design knowledge (Demirkan, 2016:28). Tarling and Ng'ambi (2016) remind educators that although emerging technologies have a negative side, they can "play a catalytic role in transformative pedagogies, as much as they can also be used to support transmission pedagogies" (Tarling & Ng'ambi, 2016:562). The approach to teaching and learning is highly influenced by technology but emerging technologies can often be hindered by educators who do not believe in them. Emerging technologies can be "criticized as over-hyped and insignificant" (Amiel & Reeves, 2008:29). Nonetheless, recent studies have shown that the use of technology in the design studio supports interaction, active learning and social engagement, which are reflected in students' development of design knowledge (Demirkan, 2016:28). Bacca et al go on to state that "significant development of user modelling and personalization processes … places the student at the centre of the learning process" (Bacca *et al*, 2014:133).

*Augmented reality in education*

AR is an agile tool for education and training that is gaining significant momentum and, although it was invented in the 1960s, its novelty allows for development of innovative applications to learning. AR is believed to increase people's comprehension and visualisation of three-dimensional elements and environments (Chi, Kang & Wang, 2013). Research on AR has also demonstrated its usefulness for increasing student motivation in the learning process (Bacca *et al*, 2014:133). In this regard, Lee (2012:19) points out that AR is a particularly efficient technology in higher education as it can improve the skills and knowledge of students on theories or mechanisms of systems or machinery. The author goes on to explain that AR can engage learners in interactive ways, applying rich content from computer-generated, three-dimensional environments and/or models.

Wu *et al* (2013:15) highlight that AR has the potential to improve student's knowledge and skills and Gurevych *et al* (2021:124) state that AR offers the benefit of "self-study", which increases the audience's interest in the educational material and, consequently, stimulates a desire to use modern interactive technical capabilities and technologies. Another advantage of AR from an educational point of view is that AR environments have been known to increase students' motivation and interest, which in turn may help them develop better investigation skills and gain more accurate knowledge on the topic (Wu *et al*, 2013:46). One may also argue that AR may stimulate and improve spatial awareness, as it may help to ground the user's reality especially where AR uses geolocation with applications that require spatial criteria.

Lee (2012:19) states that AR learning lends itself to constructivist learning where students can develop and control the construction of their own knowledge by not only using their previous experience but also allow them control of their learning which can lead to an authentic style of education and training. AR technologies can blur the boundaries between inside and outside of the classroom and between formal and informal learning settings, where a context is and what is meant by contextualization may be re-defined (Wu *et al*, 2013:48). There are different types of teaching and learning approaches, such as problem-based, simulation, etc. Hence, Wu *et al* (2013) state that there is much written about AR but not much about why AR works and how it aligns with teaching objectives (Bronack, 2011; Wu *et al*, 2013:4).

## Research methodology

### *Research design and objectives*

This paper reports on the first phase of a two-phased action research project in a department of architecture at a comprehensive university, where the benefits of AR in AEC were explored in a particular learning unit. An action research design is usually applied where an educator wants to improve a current situation (Mertler & Charles, 2010). It was viewed as an appropriate research design in this study as there were two overarching problems that were identified in the module, Architecture Technology and Detailing (ATD): 1) there was a lack of student engagement (consequently in the architectural programme at the institution, the module is generally challenged with low throughput rates below the institution's 85% benchmark), and 2) there was a lack of an AEC component in the architecture curriculum which required such an interdisciplinary component to be more relevant for the future.

Certain contextual information further exacerbated the problems within the module:

- Technical educators within this programme shared their frustrations with troublesome concepts linked to the transition to higher education particularly linked to important aspects such as understanding Construction Methods, Assembly and Materials.
- Given the global COVID-19 pandemic in 2020 and 2021, access to construction sites became restricted, which also meant practical experience with Construction Methods, Assembly and Materials was restricted.
- Technical concepts could thus be presented through limited media such as technical drawings, images, and videos leaving learners with a very theoretical understanding of how certain construction methods and assembly are applied in practice.

The above aspects represented an opportunity to widen access and consider reliable, yet comprehensive teaching aids that may contribute to distance and blended learning within the ATD module. It was argued that AR could offer possibilities to overcome the identified challenges but also to meet the following objectives: 1) explore the possibilities of enhanced student engagement and in this way improve their technical understanding, 2) explore possibilities of an interdisciplinary component, particularly with reference to engineering and the built environment, within the current curriculum.

*Research approach*

A qualitative approach was taken to meet the objectives set in the first phase. A qualitative approach is used when the objective is linked to the logic of validation as opposed to generalisation (Koro-Ljungberg, 2008). Since the aim was to explore the application of AR in a particular context, a qualitative approach was suited to the first phase of this study. Context is thus of critical importance for the validation of the applicability of AR in the module and to explore what such application entails for the curriculum as well. Consequently, a smaller number of participants was suitable to make meaningful contributions in this study provided they are suitable candidates to do so, and that data saturation could be obtained (consensus amongst the themes identified).

*Sampling*

A selected working group of participants was set up in the department of architecture to explore the possibilities of AR in the ATD module particularly in a learning unit such as Construction Methods, Assembly and Materials that is usually bounded by two-dimensional sketching and video material when taught. The participants of the working group consisted of eight technical lecturers involved in the department of architecture. Principles of a Delphi expert panel were used to guide the number of participants proposed by Sekayi and Kennedy (2017), who mention that the norm is between five and fifteen experts in a group and that they need to reach consensus. The eight participants were therefore deemed appropriate. Purposive sampling criteria were used to ensure each participant was able to make a meaningful contribution as Creswell (2013) suggests. The following selection criteria were applied to elect participants.

- All participants had to be involved in the teaching of the module in some way.
- All participants were required to have at least five years of professional experience (five years is viewed as significant in the architecture profession and, thereafter, practitioners are not viewed as junior anymore). The rationale for this was that their professional knowledge and skill on construction methods, assembly and materials would enhance their judgement of the applicability of the technology.
- At least three years of teaching experience was required in order to guide the pedagogical objective of the project with the view that they would co-own the process and adopt it into their own curriculum for teaching ATD.

From the lecturers in the department eight participants were selected as they fit the above criteria. The eight participants were briefed and gave their consent to participate.

*Method*

A demonstration was given to these lecturers with an AR application called JigSpace on a mobile device. Participants were encouraged to then explore the AR tool. Group discussions followed, facilitated by the researcher, on the relevance and possibilities of application in the field as well as possible concerns where the AR lacked in their opinion. The discussion was led by the researcher, who also demonstrated the AR by building a three-dimensional model for a typical first-year class (Figure 1).

The model shown in Figure 1 was also used as a stimulus for discussion on the possibilities of the AR tool for curriculum development. Detailed notes were made on all the discussions while voice recording was undertaken with the permission of the participants. Participants were then encouraged



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to experiment and to make observations of the AR tool, reflect on its appropriateness and to consider which models could suitably be applied to their own year-level course in ATD.

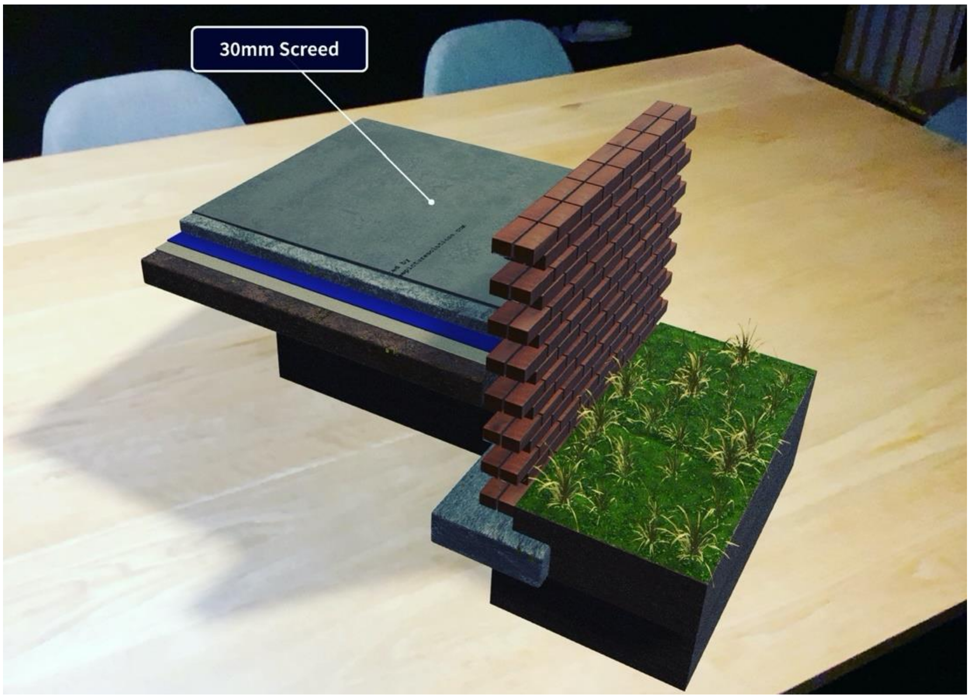


Figure 1: Example of a first-year construction model in AR used as a stimulus.

## Findings

The findings are offered according to the objectives set for this phase of the research.

*Exploring the possibilities of enhanced student engagement and improved technical understanding*

From the discussion with participants when the AR tool was demonstrated and explored, the participants pointed out that ATD is a core module in the architecture bachelor and diploma programmes, that it is technically complex, and that AR and project interventions incorporating AR seem to present an opportunity to improve access to and comprehension of this module. The possibilities and concerns were identified in five main themes, which all participants reached consensus about. These themes are summarised in Table 1.

Table 1: Participant's views on possibilities and concerns regarding applicability of AR in an ATD module

| **Theme** | **Identified concerns** | **Identified possibilities** |
|---|---|---|
| Students' ability to be technically creative | The intervention should not always provide anecdotal answers to construction problems. | Educators could find ways to enhance creativity in AR projects. |
| A principled approach to construction technology | None were noted in this theme. | AR offers the potential to develop students' understandings as a principled approach to construction technology. |
| The principle of scaffolding and progression | At senior levels, students need to engage with AR to yield greater innovation. | At year one and two, typical and standard details can be presented with alternatives.<br>At senior levels, students could begin to be more principle-based, foster the development of their own models and share them with the educator and peers to develop a more engaged studio. |
| The role of other teaching modes in relation to AR tools used | Caution should be taken not to displace other modes of learning when AR tools are used. | AR incorporated in projects should supplement the shortcomings of traditional teaching modes. |
| Three-dimensional understanding and link to two-dimensional drawing | A large part of one's interpretation and deep understanding of material and hence construction pertains to some form of tactile quality of a three-dimensional object. Although AR does not facilitate a tactile experience, it does assist with three-dimensional visualisation. AR partially addresses learning needs but does what it can do comprehensively. | AR can assist with fostering students' three-dimensional understanding of a model and tracing it back to two dimensional technical drawings. It can therefore help students to understand two-dimensional drawings. |

It was clear that although the participants were excited by the possibilities of the application of AR in the project, some risks or concerns were noted, which would need to be managed accordingly. Participants nonetheless saw the benefit and engaged the forum to develop new experimental ways of including digital platforms into a curriculum to increase an understanding of technical construction. There was however consensus that AR in projects is not an ultimate solution, but it is a way forward for pedagogical transformation.

*Exploring the possibilities of an interdisciplinary component particularly with reference to engineering and the built environment*

The general sentiment among participants was that AR could enable architectural educators in ATD to make complex models available to students on their mobile devices. Furthermore, by offering an immersive and interactive three-dimensional visualisation of models on the learner's mobile device, they may overcome the learning barriers which contact teaching often creates. There was consensus among participants that a set of technical construction models could be developed that align with the ATD curriculum outcomes to be loaded onto an AR device which would be facilitated by the educators for the learners as a teaching tool to develop a deeper understanding of Construction Methods, Assembly and Materials.

After participants were encouraged to explore the AR tool and to view various other sample three-dimensional models, the following aspects were noted as the value they experienced through the technical construction models that they built.

- Firstly, the group of participants noted that implementation of the studio session can allow the students to view, zoom, pan and rotate the technical models in three dimensions at a one is to one scale (realistic scale) by overlaying the virtual model onto a real-time camera view. The students may thus have full control over viewing the model. This finding correlates with the notion of a learner that will be able to interact and engaging in self-study, confirmed by Gurevych *et al* (2021:124).
- The second major function of the model noted, was to view the model not only as a whole, but also as crucial components that make up the model and perform various functions. This was noted as something that could provide access to the technological materials, structure, functions, and assembly.
- Thirdly, the participants all noted that the model is dynamic. The application allows the model to be exploded in stages and this allows sequential understanding of the steps taken to assemble the construction in real life. This is in line with the observation of Kerr and Lawson (2020:8) who state that an advantage of AR is that it is dynamic and not static.

Bearing in mind the findings from objective one and the exploration of the possibilities for an interdisciplinary component particularly through three-dimensional modelling, Table 2 presents the possible curriculum outcomes suggested by participants for the various year-levels.

Table 2: ATD curriculum outcomes proposed by participants

| **Year-level** | **Consensus on proposed module purpose** | **Consensus on proposed outcomes** |
|---|---|---|
| First year | To introduce students to fundamental construction methods, materials, services, structures, detailing and working drawings relating to simple domestic structure. Theory and application of materials and technology will be explored as extensions of concepts – considering 'technology' as an integral component of the design process. | Knowledge of construction methods and uses for materials related to simple, low-rise building types; ability to develop durable, cost-effective, climate-responsive construction details;<br>Ability to conduct limited relevant research into construction methods and materials and the appropriate applications;<br>Knowledge of the basic structural concepts pertaining to buildings. |
| Second year | To develop students' understanding of construction methods, materials, services, structures, detailing and working drawings relating to simple domestic structure. | Design and detail simple structural systems, floor slabs, beams, staircases, roof structures;<br>Select and specify appropriate services and fittings;<br>Select appropriate foundations;<br>Select materials used and the construction of walls, floors and walls;<br>Design openings in the walls, arches, doors and windows;<br>Select and design appropriate roof support systems, materials and finishes;<br>Select appropriate finishes and building components;<br>Prepare a complete set of contract documentation for an intermediate building with framed structure;<br>Develop assembly details that are in keeping with their design concept, workable and practically executable. |
| Third year | To develop the student's ability to select and incorporate appropriate structural systems, construction methods, materials, building services and systems into the design of less complicated buildings in consultation with various other professions. | Identify and explain structural concepts pertaining to medium-rise buildings;<br>Select and illustrate appropriate construction methods and selection of materials related to structurally simple buildings;<br>Explore and apply sustainable construction methods and technologies;<br>Produce a set of working drawings of buildings of medium structural and pragmatic complexity as part of a set of contract documents to acceptable academic and practice standards;<br>Document durable, cost-effective, climate-responsive construction systems;<br>Specify components and materials on drawings;<br>Link/relate regulatory standards and relevant municipal laws to projects. |

## Conclusions and implications

In this paper, the argument is made that it is important that educators keep abreast of technological advancements in emerging technologies through education and training because educators need to prepare future-fit students for a dynamic industry. Although educators hold specific sets of gained knowledge which is required to form a traditional body of knowledge, I argue that it is important for



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some educators to develop a pragmatic and design-led practice to develop a deeper understanding of their knowledge in relation to emerging technology and the industry. AR is useful in supplementing methods in TEL. It can enhance education in ways which cannot be physically achieved and may also have a logistic benefit in the sense that students do not have to always go into the field to experience a three-dimensional phenomenon in order to access certain aspects of knowledge pertaining to, for example, Construction Methods, Assembly, and Materials. It was clear from the finding that simulations of workflows may offer some solutions to the current challenges brought about by the pandemic that conventional teaching cannot address. An additional aspect of AR in TEL which is significant is widening learner participation as the participants in this study experienced first-hand.

AR addresses some of the shortcomings of teaching ATD and the larger AEC curriculum and requires a hand-on approach to exploring the opportunities which emerging technologies can provide. I argue that AR is an exciting and versatile medium which can bridge the limitations of construction site access, take advantage of new technological media, and provide safe, enhanced semi-immersive learning through a hand-held device. However, AR projects needs to be mapped out, inclusive of other educators and it requires time, funding and strategy. With strategies in place, educators could see more TEL projects being undertaken with the pursuit of exciting pedagogical transformation occurring in our education and training sites.

Despite the positive account of AR, there are also limitations to AR in that, firstly, students need access to a mobile device with the latest operating software. Secondly, students require access to the application called JigSpace which allows the viewing of AR models. Thirdly, although there are a range of standard models in the JigSpace library, in this project, we had to create our own technical models and load these onto the application. Therefore, development of custom models is required. Fourthly, JigSpace only operates on Apple operating system devices, and it requires a stable internet connection. Finally, the JigSpace application allows free use for limited storage space; however, there is an 'in-app' function to purchase more storage. With this stated, this type of learning is heavily dependent on financial and technical resources, and it would require educators to make the necessary procurement and logistical efforts to pursue such an approach to TEL. In addition, it is common for technology to evolve quickly, for example, to include other operating platforms like Android, and to become more affordable and accessible. Nonetheless, these challenges present as significant, particularly in a global South context.

Nevertheless, it is clear from this study that AR can be effective in assisting in the comprehension of complex information, it can improve a range of knowledge and skills, may motivate students' learning, allows students control over what they learn and how they learn, and may afford enhanced access to more students. This is yet to be empirically tested in the second phase of the project and will be reported in a follow-up paper.

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