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Mobile augmented reality learning objects in higher education

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Teachers and learners in all sectors of education continue to have access to a growing number of mobile augmented reality (AR) applications for the creation and implementation of mobile AR experiences and learning objects (LOs). In this study, affordances of mobile AR and LOs for higher education are investigated through the mobile AR platform *HP Reveal*. Digital trace data from publicly shared and published AR users' LOs were examined to investigate affordances of AR technology in educational organisations and institutions and their potential implications in areas of higher education. For this purpose, a quantitative comparative analysis of system data and content from 632 AR LOs was conducted at two instances over a 2-year interval period. Each LO was thematically coded to determine multimodal functionalities and characteristics. Further thematic coding and categorisation revealed four emergent categories for affordances in higher education: *learner interaction, collaboration, cultural exploration* and *digital storytelling*. Results also revealed increases over time in the use of recorded and online video content and the use of three-dimensional (3D) characters for educational purposes. An examination of the affordances offered by the AR platform revealed opportunities for educators to explore further interactive and collaborative uses of AR with their learners for pedagogical purposes in higher education.

***Keywords*:** mixed reality; augmented reality; mobile augmented reality; technology in higher education; learning objects; digital trace data

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Introduction

Mobile learning technologies have become ubiquitous, accessible tools for many teachers and learners in educational contexts across the globe; however, the uptake of emerging, innovative mobile applications may not always be reflected in their implementation in classrooms in higher education. Mixed reality (MR) applications, which include both augmented reality (AR) and virtual reality (VR), represent examples of such largely unexplored, state-of-the-art, immersive technologies. Recent literature suggests that the use of MR technologies can offer benefits to learners in a wide range of areas of higher education including Humanities and Arts, Social Sciences, Business, Law, Engineering and Health (Bacca *et al*. 2014; Wu *et al*. 2013). In language learning, benefits have been reported in the enhancement of vocabulary development

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(Liu and Tsai 2013), motivation and engagement (Dunleavy and Dede 2014) and collaborative, multimodal meaning-making (Ho, Nelson, and Müeller-Wittig 2011). Science, mathematics and medicine are also fields in which games, simulations and virtual worlds have shown learning outcome gains through the use of instruction with MR technologies (Merchant *et al*. 2014).

Mobile augmented reality applications

AR has been defined as 'an emerging form of experience in which the real world is enhanced by computer-generated content which is tied to specific locations and/or activities' (Yuen, Yaoyuneyong, and Johnson 2011, p. 119). The computer-generated content may consist of static images, three-dimensional (3D) objects, videos or interactive activities, such as polls or quizzes, with which users can interact through applications on desktops or mobile devices. Users can also engage with AR objects through haptics, or touching their mobile device screens, and manipulating the various types of superimposed content. These interactive elements within AR enabled through mobile devices, which users would otherwise access on a one-dimensional level through screens on desktop computers, can render informational and educational content multi-dimensional with possibilities for users to explore and discover connections between the information they are learning and their real and virtual worlds (Johnson *et al*. 2010).

HP Reveal, formerly *Aurasma,* is one of a growing number of mobile AR software applications available allowing users the opportunity to create AR experiences for their specific educational contexts, to share them publicly and to store them in individual accounts, which act as a repository for a collection of informational artefacts or reusable learning objects (LOs). In this study, the focus was on artefacts, which could provide potential value as LOs in a higher education setting. *HP Reveal* is a free application that can be downloaded for iOS and Android mobile platforms, and since the site began offering services in 2011, the number of users has been reported to surpass 200 000 (HP Reveal 2018).

Users of *HP Reveal* can create and interact with AR *auras*, or layered multimedia experiences, which are made up of uploaded image files with an overlay of another multimedia file (i.e. 3D objects, videos or audio files). As a user scans the trigger image, the multimedia object is displayed in the physical space or on the mobile user's screen. Users can choose to make their accounts private or public, and to view public AR experiences, a user must *follow* the AR content creator's account. Users can also create connections with other users socially through liking and sharing auras or user pages with others. In the field of higher education, this allows for educators or learners to interact and collaborate with others within the AR platform and for teachers or students to experience AR on their own mobile devices or devices provided by an educational institution.

Research questions and methodology

The study was guided by the following research questions:

RQ1**:** What types of AR LOs are posted and shared by educational institutions and organisations for educational use?

RQ2: What are some of the most commonly used types of AR LOs, and how have these changed in the past 2 years?

RQ3: What are some common affordances of mobile AR applications for educators in areas of higher education?

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A grounded theory approach (Strauss and Corbin 1994; Suddaby 2006) was used in the study conceptualisation, analysis and categorisation of publicly available digital trace data within the *HP Reveal* mobile app, offering an educational MR social network to explore implications of the content of AR LOs for higher education. The exploratory method and design of this research study was inspired by previous research using digital trace data to explore a social media/network platform, namely, Twitter, to identify content types and taxonomies from user postings for specific analytic purposes (Naaman, Boase, and Lai 2010; Teodoro and Naaman 2013).

A random selection of multimedia AR artefacts (n = 632) from 16 educational institutions and organisations, from seven countries, and their corresponding publicly available digital trace data was individually, manually tested, examined, coded and categorised through a qualitative inductive analysis. All AR objects were selected from accounts with publicly shared higher education-related data from learning centres and educational institutions: colleges and universities, libraries and museums. Each digital artefact consisted of informational or educational content created and shared through the *HP Reveal* platform. Although fitting a broad definition of the term *learning object*, the digital artefacts were each classified as such according to the IEEE Learning Technology Standards Committee (2002) definition as 'any entity, digital or non-digital, that may be used for learning, education or training' (p. 3). The *HP Reveal* platform was selected because it was the only open marker-based AR platform found within the research for education allowing for users to follow, like and share interactive auras, or AR experiences. In addition, the auras featured within this platform allow for collaboration, social interaction and engagement among its users. An extensive search was conducted for other AR platforms; although a number of other platforms were found to exist (Layar, Junaio and Wikitude, among others), none had yet provided open search abilities and analytic data for the purpose of this study. For the purposes of this research, only public accounts with AR experiences shared for educational uses were investigated and analysed.

Data analysis

AR platform usage

Upon research of various AR technologies to examine for this research, to determine the extent to which the AR *HP Reveal* platform has a presence in the field of higher education, a search for public accounts and LOs from users identified from the 2018 top-20 ranked universities (Times Higher Education Supplement, World University Ranking, 2018) was conducted within the AR platform. As shown in Figure 1, results revealed that 70% of the top-20 ranked universities had at least one AR LO created

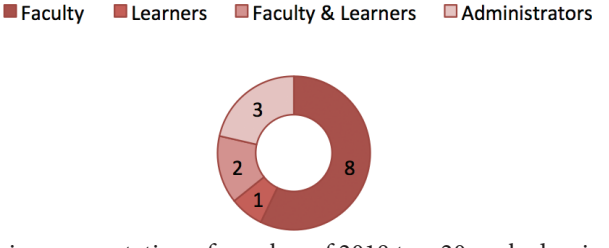

Figure 1. Graphic representation of number of 2018 top-20 ranked universities with AR accounts in HP Reveal.

on the site. The majority of users were faculty members and students; however, 15% were administrators who had created AR experiences for promotional purposes (i.e. campus tours, marketing materials, etc.).

AR learning object analysis

To gain insight into the types of educational LOs that are posted and shared through the AR platform, an inductive approach was used to analyse each of the AR LOs and their corresponding data in 2016 and 2018. Through this examination, recurring specific multimedia types were observed, and themes began to emerge about specific types of educational AR objects users had created and shared.

The process of conducting the qualitative analysis involved creating selection criteria for AR learning in the field of education. Keywords related to education (i.e. teaching, learning, education, college and university) were selected to search for higher education-related public accounts and their LOs. Each AR LO, referred to as *aura* within the application, was 'experienced' – watched, manipulated and tested – to ensure that the trigger image was connected to active multimedia content. Accounts selected for analysis did not include individual educator or student-connected data to avoid any privacy concerns that may arise from the analysis of such data, although public, without user permission. Following this, an informal affinity analysis was conducted to determine emerging patterns or themes from the AR objects.

Classification and coding

Descriptions of the types of trigger images and multimedia elements within the LOs were outlined upon analysing the variety of AR experiences. Taxonomies were assigned to each set of AR LOs, as outlined in Table 1. Adjustments, including additions and modifications, were made to the categories upon reflection and consideration of previously published research on specific uses for AR in education (Bacca *et al*. 2014; Dunleavy, Dede, and Mitchell 2009).

As results yielded LOs from outside of North America, further searches were conducted to provide representation from additional countries; AR LOs from seven

Table 1. Types of educational AR content, examples and codes assigned.

Codes assigned	Type(s) of artefacts	Example
Promotional object (PO)	Promotional videos	Campus tour
3D Moving objects (MO)	Animated 3D objects	Fireworks with a message
3D Moving character (MC)	Animated 3D character	Speaking character avatar
Audio file (AF)	Link to audio file	Artist describing artwork
Online video link (VL)	Link to online video	YouTube instructional video
Recorded video (RV)	Video recorded by the user	Student-recorded book reports
Original multimedia (OM)	Multimedia created by the user	Link to student-created podcast
Survey/Poll (SP)	Link to active poll	One or more question poll
Image Link (IL)	Link to image overlay	Image of a historical location
Link to Interactive Map (LM)	Link to map with geolocation information	Nature walk map
Combination of Multimedia (CM)	More than one type of multimedia used	Link to video + link to information on a website

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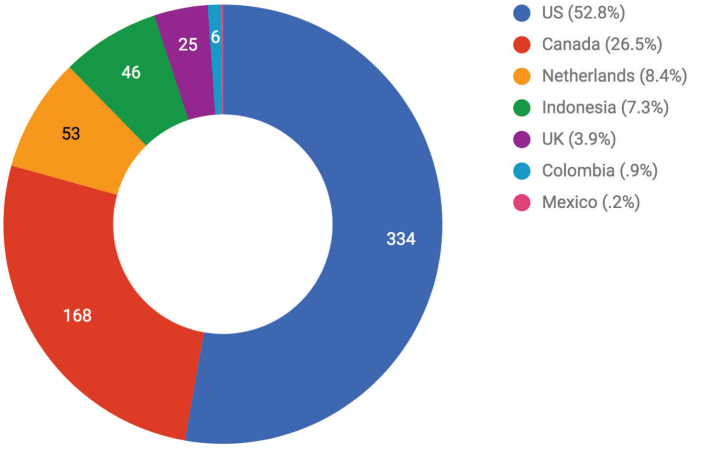

Figure 2. Countries represented in this study and the number of AR LOs analysed.

countries are represented in this study in Figure 2 (the United States, the United Kingdom, Canada, Mexico, Colombia, the Netherlands and Indonesia). Further content analysis was required to ensure the LO relatedness and relevant applications within a context for higher education.

Results and discussion

RQ1: What types of AR LOs are posted and shared by educational institutions and organisations for educational or public use?

In response to *RQ1*, examination and categorisation of each of the AR LOs yielded 11 specific types of content(see Figure 3): recorded videos, online video links, image links,

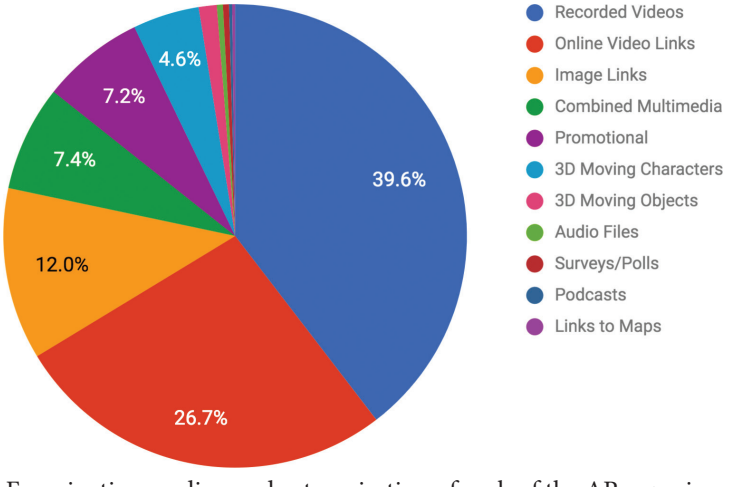

Figure 3. Examination, coding and categorisation of each of the AR experiences yielded 11 specific types of LO content.

combined multimedia, promotional content, 3D moving characters, 3D moving objects, audio files, surveys/polls, podcasts and links to maps. Most of the objects consisted of a single type of multimedia overlaid upon a trigger image; however, one category reflects more than one type of media used within one AR object. This adds an additional layer of complexity and interaction for the user and the creator of the content; however, for educational purposes, it provides additional opportunities for learning and discovery.

RQ2: What are some of the most commonly used types of AR LOs, and how have these changed in the past 2 years?

To address RQ2, further classification and coding of the AR LOs revealed that the five most commonly used types of content from the 2 year data set are trigger images linked to the following: online videos, user-recorded videos, other online images, a combination of multimedia elements superimposed upon one object (i.e. link to a video and a link to information on a website) and promotional educational content. While each of these types of LOs can offer information or content delivery options, they also afford opportunities for user interaction and collaboration among multiple mobile users.

To determine whether there were any changes in LO types, the accounts with instances of AR LOs were revisited and the LOs were counted and analysed to reveal whether different types of multimedia were used from year 1(2016) to year 2 (2018). Comparative analysis results revealed (see Figure 4) that most categories remained consistent, while there was a significant increase in the following types of LO content: 3D moving characters (50%), online video links (45%) and recorded videos (14%). These findings could indicate a shift to educators creating more original AR content, and potentially a greater comfort level with implementation of 3D objects within AR content as 3D objects have become more accessible for use in education.

RQ3: What are some common affordances of mobile AR applications for educators in areas of higher education?

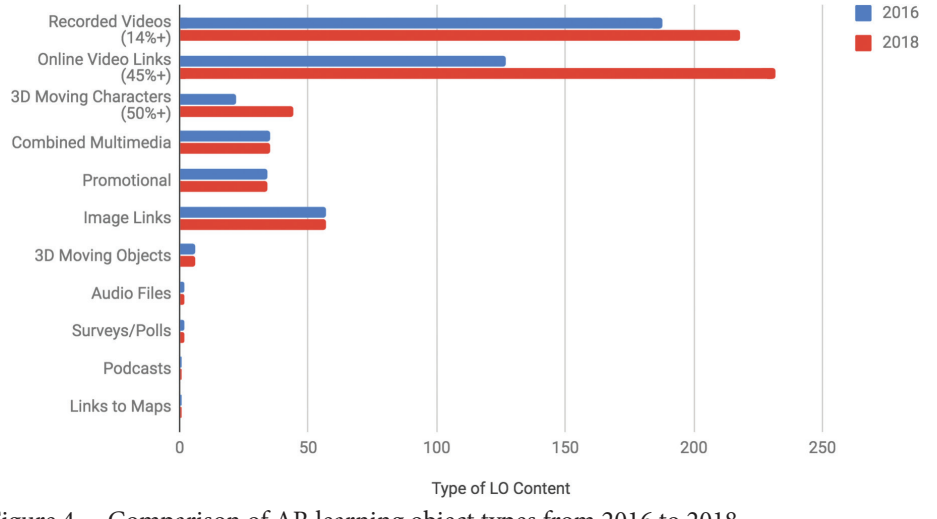

Figure 4. Comparison of AR learning object types from 2016 to 2018.

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Categorisations of affordances in technology can vary from simple interactions to more complex descriptions of strengths or weaknesses of specific functionalities (Gaver 1991). The range of complexity of affordances for AR in education has been illustrated throughout the growing body of research in this area (Dunleavy, Dede, and Mitchell 2009; Radu 2014); however, the scope of this study has been limited to centre on the exploration of noted key themes identified throughout the literature. This led to the inclusion of only a limited selection of overarching affordances in this study. Through classification of each LO from both 2016 and 2018 into categories related to affordance types frequently identified in published studies and meta-analyses in AR in education, four key affordance category types emerged for this educational technology tool in higher education (see Figure 5):

1. Learner interaction
2. Cultural exploration
3. Digital storytelling
4. Collaboration

Figure 5 indicates affordances for this type of mobile AR application, which are relevant in a wide range of areas of higher education. Classification and the coding of the grouping of the LOs were performed on the basis of the content of each LO and any instructions or descriptions provided indicating a potential main purpose for the educational use of the AR in the users' specific educational contexts. For example, a university faculty member's LO including a trigger image of a painting linked to a website with more information about the background, life and culture of the artist would be considered an activity for *cultural exploration*. In analysing each LO, insight could be gained into such overarching themes of potential affordances in higher education for this mobile AR application.

While the strength of mobile MR, and AR use specifically, lies in the interactive nature of the technology, further opportunities exist for the creation of mobile AR LOs to provide opportunities for collaboration among learners while using the technology, digital storytelling and other interactive activities, such as polls and surveys.

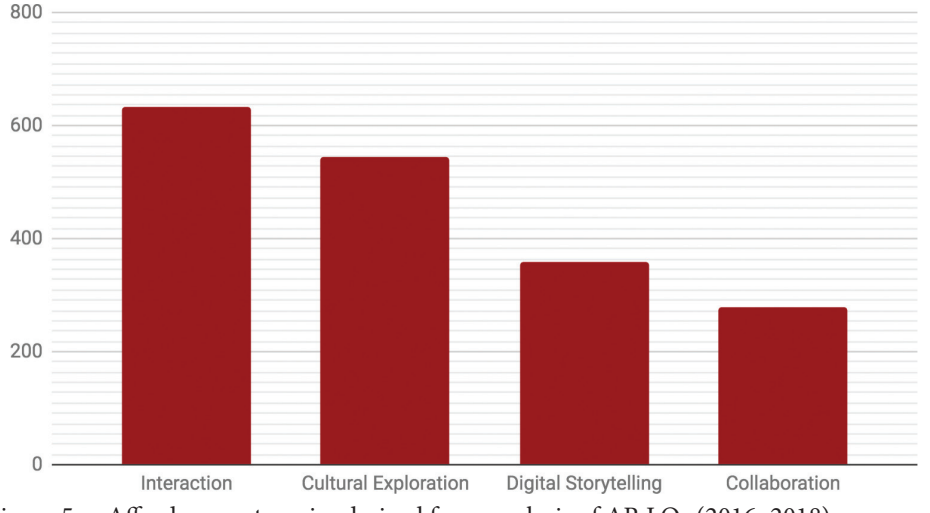

Figure 5. Affordance categories derived from analysis of AR LOs (2016–2018).

For example, group scavenger hunts or incorporating action-oriented activities when creating AR LO may allow for more collaborative interaction in AR activities in higher education settings.

Limitations and recommendations

While this research addresses multiple calls-to-action in academia for the need for empirical based research in the field of MR in education (Bacca *et al*. 2014; Merchant *et al*. 2014), the study is not without limitations. The following are some of the limitations and challenges encountered and recommendations for future design modifications to improve AR experiences and platforms for higher education:

- Users are required to follow a person/account to view AR LOs. While this is a function of an open-access platform, this additional step may hinder educators and learners from designing LOs for higher education purposes given the possible perceived barriers or complexity of the process. Fully open access platforms without the need for registration or the additional step of locating and following others to conditionally access content will allow for greater accessibility for both educators and learners.
- Paid AR campaigns were excluded from this research to focus on general open educational LO content; however, for business and marketing purposes, further investigation in this area would be of value for educators and learners in these fields.
- Not all LOs included dates created or posted, and only publicly available content was analysed within the scope of this study. Further research is needed from the perspective of educators and learners in their experiences with the use of AR in higher education contexts to investigate effectiveness of affordances, learner interactions and collaboration, including benefits, learning gains and drawbacks.
- To achieve a clearer understanding of each of the intended educational applications and contexts, further empirical research, potentially using additional qualitative methodologies, including teacher interviews or focus groups, would provide greater insights into specific affordances of AR LOs in educational contexts.
- Although it is possible to see the number of followers and likes on an AR object, it is not possible to see the number of views or interactions. Including this analytic information would provide useful insight for educators for formative or summative evaluation purposes.
- In the current iteration of the software, there is no place to comment and encourage further interaction or collaboration of users within the mobile application. Future developers of iterations of this or other AR software may consider including this optional functionality to enhance interactivity and collaboration among users.

Conclusion and future considerations

MRs and AR creation platforms like *HP Reveal* are becoming more easily accessible for educators and learners in higher education around the world. Through this analysis of publicly available AR LOs online using digital trace data, results show that AR experiences can be created using rich and varied, simple or complex multimedia content for diverse pedagogical purposes and affordances within higher education. The present study, despite its limited scope, also supports results reported in existing

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peer-reviewed, published research in the fields of MR, which confirms that AR may be an educational technology tool chosen by educators for a number of purposes, among some of which are *interaction*, *collaboration, digital storytelling* and *cultural exploration* (Bacca *et al*. 2014; Bimber, Encarnação, and Schmalstieg 2003; Radu 2012, 2014). In addition to adding to the body of research in MR, technology and education, this work offers some insights for educators as users of mobile AR applications seeking to enhance the learning experience in higher education classes. It also builds on the growing field of research utilising digital trace data to investigate social media platforms to understand human behaviour (Naaman, Boase, and Lai 2010; Teodoro and Naaman 2013).

There is also an increasing number of applications, which allows educators to create AR experiences and LOs without the requirement of the knowledge or skills in programming, and higher education institutions are currently recognising, exploring and implementing various MR technologies to provide innovation and experiential learning opportunities in more traditional classroom settings (Becker *et al*. 2017). In conclusion, it is evident that further empirical research, both qualitative and quantitative, is needed in this field to investigate practical implications, additional specific affordances and the potential for learning gains within each affordance category. It has also become evident that as educators in the fields of higher education continue to seek to create and develop novel educational opportunities to encourage interaction and engagement among their learners, the continued exploration of AR and MR technologies is an option notably worthy of consideration.

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